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STANDARDIZATION OF THE OPTICAL DENSITIES OF INDUSTRIAL EYE-PROTECTIVE GLASSES

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Abstract

In this paper the methods employed in the establishment of accurate standards of spectral and luminous transmittance of the various shades of eye-protective glasses are described. Data are given on the transmittances of these standards and their applications in the laboratory and in industry.

Through the use of these standards the spectral-transmissive properties of various new eye-protective glasses for use in industry have been determined. Representative data are given in a group of transmission curves.

I. Introduction

The establishment of standards of density for eye-protective glasses was first attempted a number of years ago through the use of optical density wedges[1] with measurements being made visually on a Martens polarization photometer by a number of observers. The wedges were made of welding glass with ranges in thickness such that optical density values corresponding to the density range for one to two shades were incorporated into each wedge. Several defects in this method soon became apparent. The area of the wedge under examination in the instrument covered an appreciable range in density, since the length of wedge for a full shade was of the order of only two to three inches. Furthermore, it was found that individuals who presumably possessed normal color vision obtained different readings on the visual photometer; also that the same individual obtained variable readings depending upon previous activities, time of day, etc.[2]. The whole process became confused—including the use of optical density wedges—so that the entire idea has been discarded in favor of using spectral transmittance measurements together with luminosity data for a standard of color temperature[3, 4].

The relative spectral luminosity curve for the "average" eye has been established through a number of controlled research studies[4-14] wherein several hundred observers were tested. The accepted I.C.I. values, recommended to the International Commission on Illumination by Gibson and Tyndall[4, 13], were obtained from a graphical compilation of all of the existing [in 1923] luminosity data for daylight vision in which more than 10 observers were used. These values are tabulated in Table 1 and shown graphically in Figure 2.

The color-temperature value employed in this work is taken as the standard 1931 I.C.I. illuminant A[15-17] which is essentially that of a tungsten lamp operated at a color temperature of 2848°K ($C_2 = 14{,}350$). This is near the normal operating color temperature of present-day high-wattage tungsten-filament incandescent lamps, and is therefore in accordance with past work in the measurement of densities of welding glass under the Federal Specifications[18]. The luminosity factors for a color temperature of 2848°K ($C_2 = 14{,}350$) are found as a product of the relative spectral energy values for illuminant A and the relative spectral luminosity values for the eye. These data are given in Table 1, after having been revised to a sum of 100,000 to simplify luminous transmission calculations.

The basis for shade number classification of eye-protective glasses was established about 20 years ago in the setting up of a mathematical formula which gives the relation between optical density, luminous transmittance, and shade number. The formula is:[1, 19, 20] optical density $= 3/7$ (shade number -1) $= \log_{10}\left(\frac{1}{\text{transmittance}}\right)$

In this formula the optical density has the usual meaning, being the logarithm of the opacity; that is, the logarithm of the reciprocal of the transmittance. For example, shade No. 8 (see Table 2) has an optical density of 3.000 and consequently a transmittance of 0.100 per cent (since 3.000 is the logarithm of 1,000).

The formula is simple and correlates the optical densities of the different shade numbers in such a way that if the

TABLE 1—*Luminosity Data*

Relative energy distribution of Illuminant A (1931 I.C.I. standard for colorimetry, Planck 2848°K, C_2=14, 350); spectral luminosity for the average eye (1924 I.C.I. standard); and luminosity factors for illuminant A.

Wavelength Millimicrons	Relative Energy Illuminant A	Relative Luminosity	Luminosity Factors
400	14.71	0.0004	1
410	17.68	.0012	2
420	21.00	.0040	8
430	24.67	.0116	27
440	28.70	.023	61
450	33.09	.038	117
460	37.82	.060	210
470	42.87	.091	362
480	48.25	.139	622
490	53.91	.208	1039
500	59.86	.323	1792
510	66.06	.503	3080
520	72.50	.710	4771
530	79.13	.862	6322
540	85.95	.954	7600
550	92.91	.995	8568
560	100.00	.995	9222
570	107.18	.952	9457
580	114.44	.870	9228
590	121.73	.757	8541
600	129.04	.631	7547
610	136.34	.503	6356
620	143.62	.381	5072
630	150.83	.265	3705
640	157.98	.175	2562
650	165.03	.107	1637
660	171.96	.061	972
670	178.77	.032	530
680	185.43	.017	292
690	191.93	.0082	146
700	198.26	.0041	75
710	204.41	.0021	40
720	210.36	.00105	20
730	216.12	.00052	10
740	221.66	.00025	5
750	227.00	.00012	3
760	232.11	.00006	1

sum of the densities of any two shade numbers is taken, it will be that for a shade number one less than the sum of the two shade numbers concerned. For example, take the optical densities of shades 3 and 8 which are 0.857 and 3.000 (see Table 2) and whose sum is 3.857, the optical density of shade No. 10 (3+8—1=10). In a similar manner the transmittance of a given shade number is 1/1000 or 0.1 percent of that for a glass seven shade numbers lighter.

In Table 2 are given the transmittances and tolerances in transmittances (also optical densities and tolerances in density) of the various shades of eye protective glasses from shade 1.5 to 14.0 as defined by the optical density-transmittance-shade-number formula above. These values vary slightly from the original data incorporated in the Federal Specifications[18] in that they eliminate small gaps previously left between the different shade-number ranges. This revision is now under consideration for inclusion in the new editions of the Federal Specifications to bring the optical density and transmission data into precise agreement with the optical density-transmission-shade-number formula and to include all density and transmittance values within some shade number thus insuring against the waste of material in manufacture.

The stringent requirements of the specifications[18] promulgated by the Federal Specifications Board for eye protection have reduced the number of colored glasses that are suitable for use in protecting the eyes of industrial workers to a relatively few types. Many of the sun glasses used for outdoor wear[21] are unsuited for use in industry because of high ultraviolet or infrared transmittances or because of poor mechanical or optical characteristics. Only representative samples of those glasses which generally conform in mechanical and optical properties with the Federal Specifications will be considered in this discussion.

II. Instrument and Methods of Measurement

Glasses suitable for welding and associated operations are necessarily very opaque to both the ultraviolet and infrared regions of the spectrum, and therefore, even in the lighter shades, the opacity is high in the red and blue ends of the visible spectrum as well. The optical densities of the darker shades are very high (transmittances very low) throughout the visible spectrum. It is therefore necessary to use special methods to obtain accurately the spectral and luminous transmittances in the visible spectrum.

In this work a Beckman quartz spectrophotometer[22, 23] was employed, readings of transmittance being made at 10 millimicron intervals within the spectral region of 400 to 760 millimicrons. For the lighter shades—that is, where the optical density was not greater than about 1.0 (transmittance 10 percent)—the transmittance was determined directly without the use of a standard comparison sample. For the darker shades, where the transmittance is of the order of a small fraction of one percent this procedure could not be followed because of instrumental errors often many times as large as the transmittance of the glass.

In the Beckman quartz spectrophotometer the transmittance (or optical density) is indicated on a potentiometer scale which is linear with transmittance. Hence all high optical density values (above 1.0 to 1.5) are crowded into a small portion of the scale so that optical density settings above 1.0 become increasingly imprecise. Some increase in precision is obtainable through the use of the high sensitivity potentiometer scale wherein the scale sensitivity is increased by a factor of ten. However, little is gained since the accuracy of the measurement is in all cases limited by the stability of the instrument amplifier and phototubes[22].

Through the cooperation of Mr. E. L. Hettinger of Willson Products, Inc., Reading, Penna., a large quantity of welding glass ranging in density from shade 1.5 to 14.0 was placed at the disposal of the Bureau for use in setting up standards of total and spectral transmittance for the different shade numbers.

For use in establishing these shade number standards a group of three primary standards was first set up through intercomparisons within a group of about 25 glasses ranging in optical density from shade No. 1.5 to

6.0. That is, in this work, a number of independent intercomparisons were made in establishing each of the three standards. The first step was the direct measurement of the spectral transmittance of a group of light shade glasses (shades 1.5 to 2.5) on the Beckman spectrophotometer followed by a comparison of each with a dark sample of Calobar (identified as DK) which became standard No. 1. Next a group of glasses having optical densities near the values for shades 2.5 to 3.0 were compared with standard No. 1 and with a certain Willson-Weld shade No. 3 glass (identified as 3A) which became standard No. 2. Finally, a third group of glasses having optical densities ranging from the values for shade 5 to shade 6 were compared with standard No. 2 and with a certain Bausch and Lomb shade 6 glass (identified as 6A) which became standard No. 3.

In order to verify the accuracy of this work a check measurement was made by the photometry and colorimetry section of this Bureau on standard No. 3 (identified as 6A in Figure 1), by measuring its spectral transmittance at various wavelengths from 390 to 740 millimicrons on two Beckman photoelectric spectophotometers (directly and through the use of other standards[23]) and on a Koenig-Martens spectrophotometer[24] at the same wavelengths from 435.8 to 660 millimicrons. The values indicated by dots (see Figure 1) were obtained by the photometry and colorimetry section while those indicated by circles were observed by the author. The very close agreement (at 4 points the values coincide) between the two laboratories is gratifying.

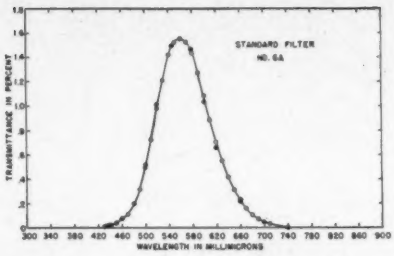


Fig. 1. ***Spectral transmittance of Standard Filter No. 6A.*** **This is the darkest one of the standard filters used as comparison standards in this investigation. The values represented by the open circles were obtained in the Radiometry Laboratory by the author; those represented by the solid circles by the Photometry and Colorimetry Section.**

III. Shade Number Standards

In the establishment of the secondary standards for luminous and spectral transmittance for each of the shade numbers preliminary measurements were made on a Martens polarization photometer, or on a photometer consisting of a Weston photronic cell covered by a viscor filter, in order to select samples of welding glass having optical densities near the division points between the various shades. Much of this preliminary work was kindly done by Mr. E. L. Hettinger and Miss Morrett of the Willson Products Company.

Several samples of glass having transmittances near the minimum and maximum optical densities (or percent transmittances) were selected for each shade number and their spectral transmittances accurately determined with a Beckman quartz spectrophotometer[22, 23] at 10 millimicron intervals throughout the visible spectrum as was

TABLE 2.—*Transmittances and tolerances in transmittance of various shades of filter lenses*

The values given apply to Class I filter glass. For Class II filter lenses the transmittances and tolerances are the same with the additional requirement that the transmittance at 589.3 millimicrons shall not exceed 15 percent of the luminous transmittance.

Shade No.	Optical Density			Luminous transmittance			Maximum infrared transmittance	Maximum spectral transmittances in the ultraviolet and violet wavelength in millimicrons			
	Minimum	Standard	Maximum	Maximum	Standard	Minimum		313	334	365	405
				Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1.5	0.17	0.214	0.26	67	61.1	55	25	0.2	0.8	25	65
1.7	0.26	0.300	0.36	55	50.1	43	20	0.2	0.7	20	50
2.0	0.36	0.429	0.54	43	37.3	29	15	0.2	0.5	14	35
2.5	0.54	0.643	0.75	29	22.8	18.0	12	0.2	0.3	5	15
3.0	0.75	0.857	1.07	18.0	13.9	8.50	9.0	0.2	0.2	0.5	6
4.0	1.07	1.286	1.50	8.50	5.18	3.16	5.0	0.2	0.2	0.5	1.0
5.0	1.50	1.714	1.93	3.16	1.93	1.18	2.5	0.2	0.2	0.2	0.5
6.0	1.93	2.143	2.36	1.18	0.72	0.44	1.5	0.1	0.1	0.1	0.5
7.0	2.36	2.571	2.79	0.44	0.27	0.164	1.3	0.1	0.1	0.1	0.5
8.0	2.79	3.000	3.21	0.164	0.100	0.061	1.0	0.1	0.1	0.1	0.5
9.0	3.21	3.429	3.64	0.061	0.037	0.023	0.8	0.1	0.1	0.1	0.5
10.0	3.64	3.857	4.07	0.023	0.0139	0.0085	0.6	0.1	0.1	0.1	0.5
11.0	4.07	4.286	4.50	0.0085	0.0052	0.0032	0.5	0.05	0.05	0.05	0.1
12.0	4.50	4.714	4.93	0.0032	0.0019	0.0012	0.5	0.05	0.05	0.05	0.1
13.0	4.93	5.143	5.36	0.0012	0.00072	0.00044	0.4	0.05	0.05	0.05	0.1
14.0	5.36	5.571	5.79	0.00044	0.00027	0.00016	0.3	0.05	0.05	0.05	0.1

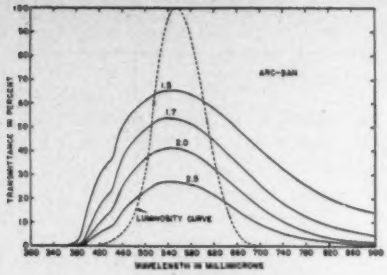


Fig. 2. ***Spectral transmittances of Arc-Ban welding glasses;*** **Also the** ***luminosity curve of the eye.*** **Arc-Ban shade No. 1.5, t = 2.92 mm, Arc-Ban shade No. 1.7, t = 3.97 mm, Arc-Ban shade No. 2.0, t = 3.28 mm, and Arc-Ban shade No. 2.5, t = 2.46 mm, Bausch and Lomb Optical Company.**

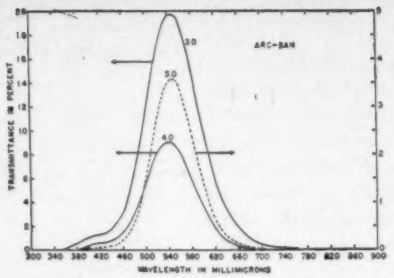


Fig. 3. ***Spectral transmittances of Arc-Ban Welding Glasses.*** **Arc-Ban shade No. 3.0, t = 2.51 mm, Arc-Ban shade No. 4.0, t = 2.83 mm, and Arc-Ban shade No. 5.0, t = 2.47 mm, Bausch and Lomb Optical Company.**

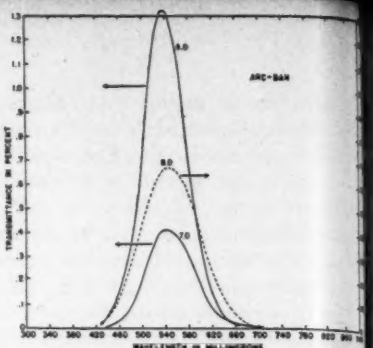


Fig. 4. ***Spectral transmittances of Arc-Ban Welding Glasses.*** **Arc-Ban shade No. 6.0, t = 2.71 mm, Arc-Ban shade No. 7.0, t = 2.27 mm, and Arc-Ban shade No. 8.0, t = 2.07 mm, Bausch and Lomb Optical Company.**

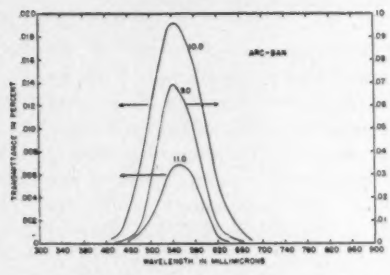


Fig. 5. ***Spectral transmittances of Arc-Ban Welding Glasses.*** **Arc-Ban shade No. 9.0, t = 3.00 mm, Arc-Ban shade No. 10.0, t = 2.62 mm, and Arc-Ban shade No. 11.0, t = 2.64 mm, Bausch and Lomb Optical Company.**

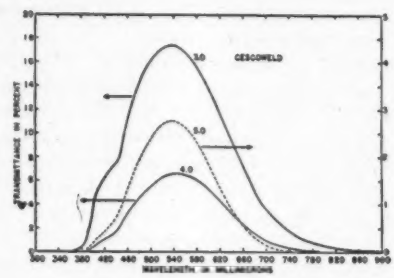


Fig. 6. ***Spectral transmittances of Cescoweld Welding Glasses.*** **Cescoweld shade No. 3.0, t = 2.59 mm, Cescoweld shade No. 4.0, t = 2.38 mm, and Cescoweld shade No. 5.0, t = 2.40 mm, Chicago Eye Shield Company.**

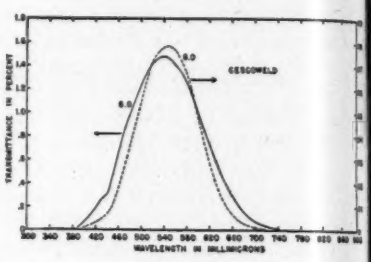


Fig. 7. ***Spectral transmittances of Cescoweld Welding Glasses.*** **Cescoweld shade No. 6.0, t = 2.56 mm, and Cescoweld shade No. 8.0, t = 2.15 mm, Chicago Eye Shield Company.**

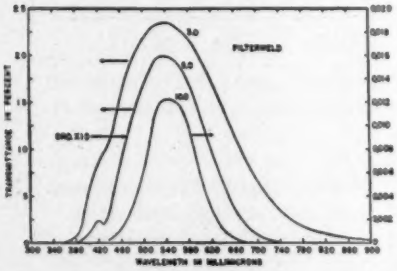


Fig. 8. ***Spectral transmittances of Filterweld Welding Glasses.*** **Filterweld shade No. 3.0, t = 2.03 mm, Filterweld shade No. 5.0, t = 2.46 mm, and Filerweld shade No. 10.0, t = 2.03 mm, American Optical Company.**

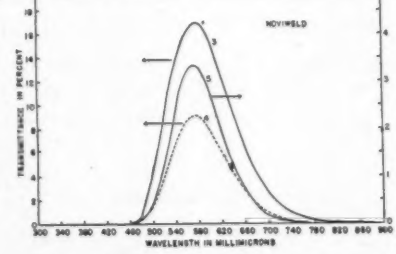


Fig. 9. ***Spectral transmittances of Noviweld Welding Glasses.*** **Noviweld shade No. 3.0, t = 2.49 mm, Noviweld shade No. 4.0, t = 2.31 mm, and Noviweld shade No. 5.0, t = 2.15 mm American Optical Company.**

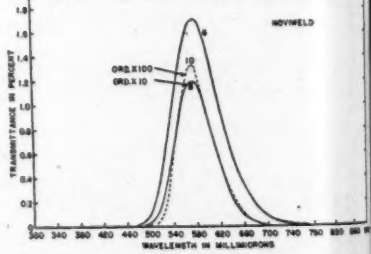


Fig. 10. ***Spectral transmittances of Noviweld Welding Glasses.*** **Noviweld shade No. 6.0, t = 1.95 mm, Noviweld shade No. 8.0, t = 2.28 mm, and Noviweld shade No. 10.0, t = 2.55 mm, American Optical Company.**

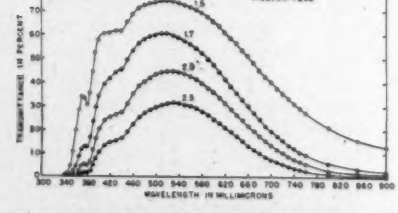


Fig. 11. ***Spectral transmittances of Willson-Weld Welding Glasses.*** **Willson-Weld shade No. 1.5, t = 3.38 mm, Willson-Weld shade no. 1.7, t = 3.12 mm, Willson-Weld shade No. 2.0, t = 3.42 mm, Willson-Weld shade No. 2.5, t = 3.25 mm, Willson Products, Inc.**

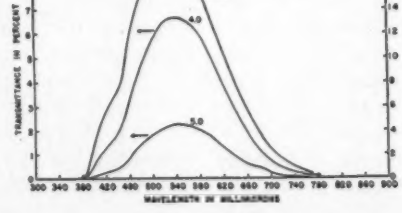


Fig. 12. ***Spectral transmittances of Willson-Weld Welding Glasses.*** **Willson-Weld shade No. 3.0, t = 3.22 mm, Willson-Weld shade No. 4.0, t = 2.50 mm, and Willson-Weld shade No. 5.0, t = 2.44 mm, Willson Products, Inc.**

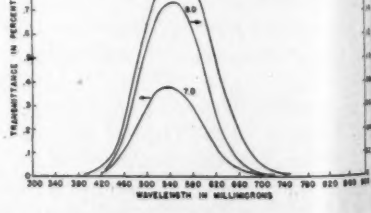


Fig. 13. ***Spectral transmittances of Willson-Weld Welding Glasses.*** **Willson-Weld shade No. 6.0, t = 2.90 mm, Willson-Weld shade No. 7.0, t = 3.04 mm, and Willson-Weld shade No. 8.0, t = 2.61 mm, Willson Products, Inc.**

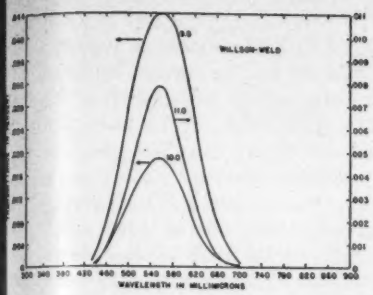


Fig. 14. *Spectral transmittances of Willson-Weld Welding Glasses.* Willson-Weld shade No. 9.0, t = 2.25 mm, Willson-Weld shade No. 10.0, t = 2.47 mm, and Willson-Weld shade No. 11.0, t = 2.78 mm, Willson Products, Inc.

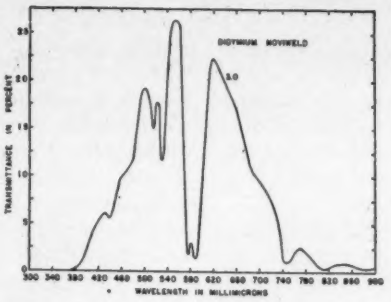


Fig. 15. *Spectral transmittances of Didymium Noviweld Welding Glass.* Didymium Noviweld shade No. 3.0, t = 3.56 mm, American Optical Company.

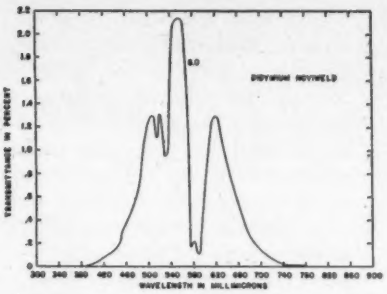


Fig. 16. *Spectral transmittance of a Didymium Noviweld Welding Glass.* Didymium Noviweld shade No. 6.0, t = 3.51, mm, American Optical Company.

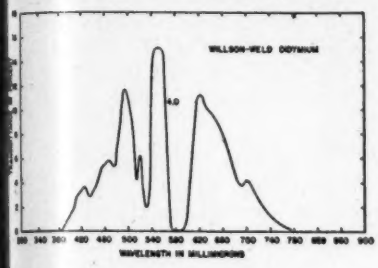


Fig. 17. *Spectral transmittance of a Willson-Weld Didymium Welding Glass.* Willson-Weld Didymium shade No. 4.0, t = 3.58 mm, Willson Products, Inc.

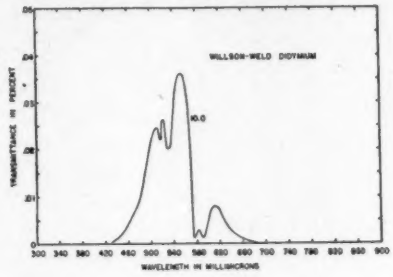


Fig. 18. *Spectral transmittance of a Willson-Weld Didymium Welding Glass.* Willson-Weld Didymium shade No. 10.0, t = 3.51 mm, Willson Products, Inc.

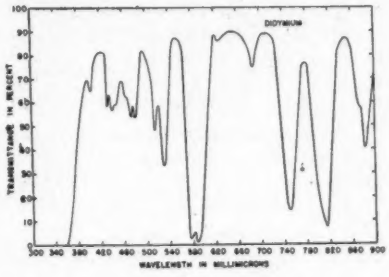


Fig. 19. *Spectral transmittance of a light Didymium Glass.* Didymium glass, t = 3.17 mm, American Optical Company, and Willson Products, Inc. This transmission curve indicates the quality of work possible with the instrument employed in the present investigation.

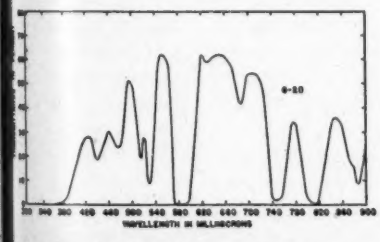


Fig. 20. *Spectral transmittance of a Didymium Glass.* Didymium glass, C-20, t = 2.99 mm, Bausch and Lomb Optical Company. This lens has a high optical density for the short wavelengths in the ultraviolet, and a reduced infrared transmittance. The transmittance at the sodium line is less than 0.5 per cent.

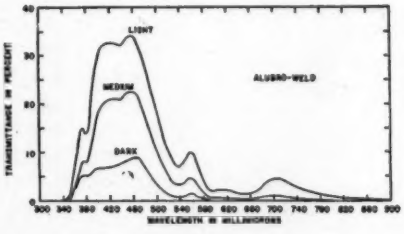


Fig. 21. *Spectral transmittances of Alubro-Weld Aluminum Welding Glasses.* Light Alubro-Weld, t = 3.01 mm, Medium Alubro-Weld, t = 3.54 mm, and Dark Alubro-Weld, t = 2.25 mm, Willson Products, Inc.

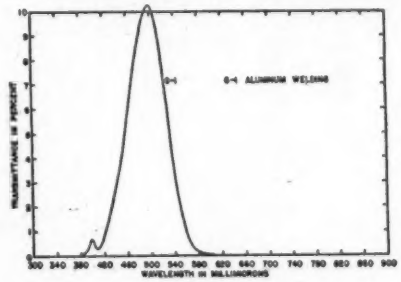
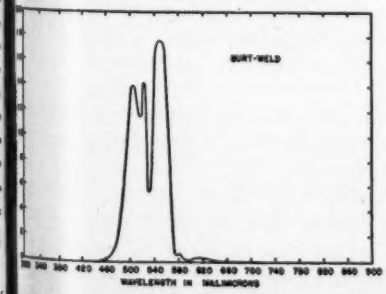
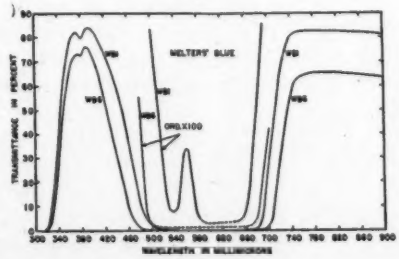


Fig. 22. *Spectral transmittance of (C-1) Aluminum Welding Glass.* This aluminum welding glass, t = 3.20 mm, from Bausch and Lomb Optical Company, is made with a high optical density for wavelengths longer than about 580 millimicrons for absorbing the sodium and lithium flares in aluminum welding. The luminous transmittance is that of a light shade No. 5.0.





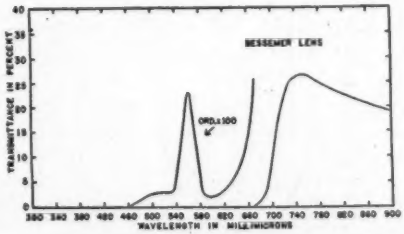


Fig. 23. *Spectral transmittance of Burt-Weld Aluminum Welding Glass.* Burt-Weld, t = 3.54 mm, B. F. McDonald Company. This glass is shade No. 4 (luminous transmittance about 5 per cent). Fig. 24. *Spectral transmittances of deep-blue Cobalt Glasses.* Melters' Blue (WB1), t = 3.05 mm, and Melters' Blue (WB6), t = 3.04 mm, Willson Products, Inc. These cobalt blue glasses are the lightest and darkest of a series of six shades of blue. Similar glasses are available in 8 shades (C1 to C8) from American Optical Company, and in 8 shades (thicknesses 3.6 to 4.3 mm) from Bausch and Lomb Optical Company. Fig. 25. *Spectral transmittance of a Bessemer Lens.* Bessemer Lens, t = 3.03 mm, Bausch and Lomb Optical Company.

done in establishing the primary standards. Except in the case of a few of the lighter shade numbers, one, or more, of the primary standards was used as a comparison sample. The spectral transmittance values were then transformed into luminous transmittances through the application of the luminosity factors (see Table 1) for a color temperature of 2848°K (C_2=14, 350).

In Table 3 are tabulated the luminous transmittances of the group of shade-number standards obtained in this work. The tolerance value for each shade-number division point is also given in this table. In most cases the standards are quite close to the maximum-minimum tolerance values. Closer agreement would have been possible through further grinding and polishing of glass samples sufficient to produce small changes in thickness. However, the extra work involved was considered out of proportion to any added convenience afforded by more nearly exact agreement between standards and tolerance values.

TABLE 3—*Shade-Number Standards*

Transmittance values of shade-number standards

Standard Shade Number	Specified Tolerance Value (see Table 2)	Transmittance of NBS Standard
	percent	percent
- 1.5	67	68.02
1.5- 1.7	55	55.17
1.7- 2.0	43	44.01
2.0- 2.5	29	30.14
2.5- 3.0	18.0	19.99
3.0- 4.0	8.50	9.05
4.0- 5.0	3.16	3.19
5.0- 6.0	1.18	1.19
6.0- 7.0	0.44	.486
7.0- 8.0	0.164	.185
8.0- 9.0	0.061	.0588
9.0-10.0	0.023	.0208
10.0-11.0	0.0085	.00864
11.0-12.0	0.0032	.00314

This group of standard glasses serves its most useful purpose as a set of go-no-go standards for determining the shade number and degree of conformity of test samples with the shade-number specifications. For this work a physical photometer in the form of a photoelectric receiver of some type, for example a photronic cell employing a viscor filter as a cover glass, is very practical for rapid, but accurate, evaluation of shade numbers. At this Bureau such a photoelectric device is employed and the response is read on a sensitive galvanometer. An experimental set up for rapid shade-number evaluation consisting of a modulated light beam (510 cycles per second), tuned a.c. amplifier, and an a.c. vacuum tube voltmeter has been found quite satisfactory, and might be valuable for use by industry.

IV. Spectral-Transmission Data on Special Filter Glasses

In a comprehensive report[21] data are presented on nearly 200 glasses for use in protecting the eyes from radiant energy encountered in sunlight, and in industry where the operator is working with or around artificial sources of radiation. In keeping with industrial progress in this country, protective glasses and goggles have been developed and improved until today there is a glass, or goggle, available for providing adequate protection in each and every occupation or avocation. It is the purpose of this section to give representative data on a few available glasses. Reference should be made to the above-mentioned report for additional information on protective glasses.

The standard (Class I) welding glasses, such as Arc-Ban, Cescoweld, Filterweld, Noviweld and Willson-weld (Figures 2-14) are similar in characteristics except for small variations in color. All of these glasses have very low transmittances in the ultraviolet and infrared, even for the lighter shades, and when properly selected for shade number meet the requirements of the Federal Specifications on filter glasses for use in goggles, helmets, and hand shields for use in welding and associated industries.

In operations such as welding with coated rods or in aluminum or magnesium welding wherein there is emitted strong radiant flux at the wavelengths of the sodium lines at 589.3 millimicrons, the use of didymium glasses, so named because they contain a mixture of the oxides of prasodymium and neodymium (Class II filter lenses), has been found advantageous. Recently, glasses of this type in shades ranging from No. 3 to No. 10 (see Figures 15-18) have been developed. These glasses are similar to Class I filter glasses in ultraviolet, visible and infrared characteristics except that they contain in addition sufficient didymium to reduce their transmittance in the region of 589.3 millimicrons to a relatively low value. Other absorption bands characteristic of didymium are present but add or detract little from the usefulness of the glass. It appears that all of these glasses contain about the same amount of didymium as judged from the relative depths of the absorption bands, the darker shades being obtained simply through the use of the denser base glass. These glasses remove almost completely the bright sodium glow surrounding welding or cutting operations, enabling the operator to clearly view his work. A further improvement is usually possible through the use of a lighter shade than could be selected from ordinary welding glasses to give comparable protection, thus gaining added visibility of details surrounding the center of operations.

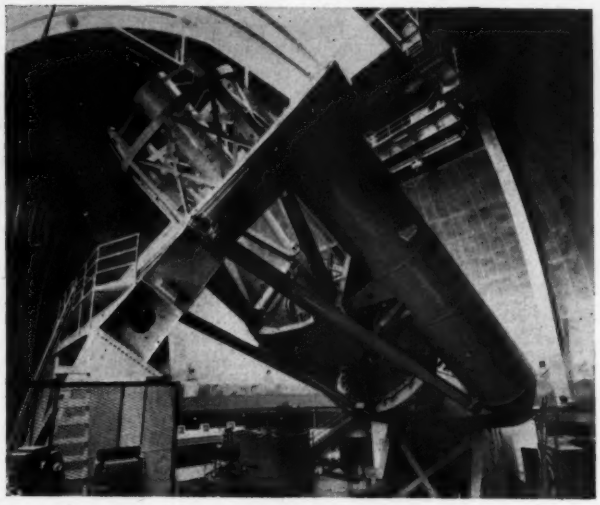
In the fabrication of glass, since it contains sodium, it gives off an intense yellow flare when heated. Because of this intense light (at 589.3 millimicrons) the glass worker has difficulty, without special glasses, in seeing the glass to bend or shape it into the desired article. It has become the practice of glass blowers to wear didymium glasses having a high luminous transmittance yet high absorption in the ultraviolet and infrared regions of the spectrum (see Figures 19 and 20) as well as at 589.3 millimicrons.

Other glasses previously developed for use in aluminum welding are shown in Figures 21, 22, and 23. All of these reduce the sodium and lithium radiant flux to a low value and will be found useful, and in many cases preferable to the special didymium glasses in aluminum

(*Continued on page* 406)

200-INCH CORNING MIRROR GOES INTO SERVICE AT MT. PALOMAR

On June 3, the long awaited dedication ceremony of the Palomar Observatory and its 200-inch telescope was held at Mt. Palomar before an audience of close to 1,000 invited guests and newsmen. The original appropriation of $6,000,000 for the undertaking of this mammoth project, a sum which was increased to $6,550,000 before completion of the telescope, was made in May 1928. During the war years, construction was completely suspended on the project and, while there still remains considerable testing and adjusting to be done, the telescope is expected to go into operation on its first research program sometime during the summer of 1948.



The man who launched the idea for this outstanding contribution to science was the late Dr. George Ellery Hale, who was also responsible for the Mt. Wilson Observatory and whose entire life was devoted to astronomy and its promotion. Dr. Hale, who died in February 1938, obtained the necessary money from the Rockefeller Foundation with which to build the telescope and although he did not live to see the instrument in operation, he did see it get under way and well on the road to completion.

Using mirrors as the basic principle and having no lens, the 200-inch telescope is classed as a reflector, not a refractor, type. The 200-inch mirror, which is the primary and largest mirror of six, is an instrument for gathering light that will enable astronomers to photograph objects a billion light years from the earth. A single light year represents 5,865,696,000,000 miles. While it is possible to look at the image in the 200-inch mirror, astronomers will use photography for research purposes. In this way, a permanent measureable record is made and can be made available to and studied by all astronomers.

Work on the 200-inch mirror was begun in a specially designed optical shop at California Institute of Technology in 1936. The mathematical computation for the mirror was under the direction of Dr. John A. Anderson, executive officer of the Palomar Mountain Observatory Council at the University, with Marcus H. Brown in charge of the mechanics of grinding and polishing.

The mirror disc was cast by the Corning Glass Works at Corning, New York. Previously, mirrors for telescopes had always been solid discs. However, in this instance, its face is solid glass and its back cellular. Casting it in this manner not only served to reduce its weight, but also provided for an innovation in mounting whereby the mirror is supported at 36 points instead of by the usual back and edge supports. The fact that the four-inch solid portion of the mirror is much thinner than would be possible with a solid casting makes it possible for it to adapt itself to temperature changes with much more rapidity, an important feature in all telescopes.

The huge disc weighed 20 tons when polishing and grinding began. In all 5¼ tons were ground and polished off its face to achieve a parabolic surface accurate to within two-millionths of an inch. The mirror now weighs 14¾ tons. Including the cellular back, it is approximately 24 inches thick at the edges and 20½ inches thick at the center. In its center is a hole 40 inches in diameter which is required for the Cassegrain focus, one of three which the telescope will have. It is not large enough to in any way affect the utility of the mirror. During grinding and polishing, this opening had a glass plug in it. To insert the plug, it was placed on a cake of ice which protruded above the surface of the mirror. As the ice melted, the plug sank slowly into position. It was removed without mishap.

The six mirrors used in the telescope, three of which are convex and three flat, are mounted so that they can be used in any combinations necessary. When not in use, they can be moved into positions where they do not obstruct other focuses.

The tube on which the 200-inch mirror is mounted is also a departure from standard practice. This was necessary because of the great weight it must support without allowing misalignment of mirrors by tube flexure. Besides carrying the weight of all six mirrors, the observer at the prime focus stage actually "rides" the telescope. This is the only telescope in the world in which an observer actually rides. The tube had to be designed so that it would not deform anywhere, or in any direction, more than a sixteenth of an inch.

To accomplish this, the tube was constructed as follows: Starting at the middle of the tube with a square section containing the declination trunnions, 20-inch I-beams lead from its eight corners converging to eight points above and below to which are attached circular rings. The lower ring supports the 200-inch mirror and its cell and the upper ring supports the cage in which the observer will ride at the prime focus. The flexure resulting from deformation of the tube, due

(*Continued on page* 413)

TECHNOLOGICAL PROBLEMS IN THE USE OF ALTERNATE FUELS IN THE GLASS INDUSTRY

By ROY S. ARRANDALE
Thatcher Glass Manufacturing Co., Elmira, N. Y.

PART II

Alternate Firing with Natural Gas and Liquid Fuel Oil Direct

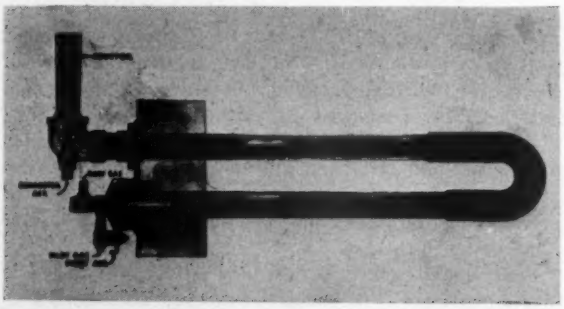
On such equipment as forehearths, where the space is necessarily confined, chances are that firing with liquid fuel directly will never be quite as satisfactory, nor as convenient, as a natural gas-fired installation by reason of the difficulty and expense in decentralizing a small stream of concentrated fuel. However, such a combination has been worked successfully on a forehearth which has a wider and higher combustion space above the glass as compared with the low and relatively narrow channel of the usual gas-fired forehearth. In this case No. 2 oil is applied direct to the channel and non-interruptible (Firm) gas on the feeder bowl itself. This gives natural gas where it is needed most and where combustion space is limited most of all. Substitution of No. 2 oil on the channel in place of interruptible gas consists primarily of swinging a gas burner away and an oil burner in its place. However, inasmuch as the light oil fire is so much more brilliant and intense than the gas, it is very seldom that more than two oil burners can be accommodated in place of six to eight gas burners. This naturally introduces an upset condition temporarily wherein it is necessary to settle the forehearth down by feel. The oil pressure regulation provided is good, however, and once the balance point in firing rate has been found, the operation is about as good on oil as it is on gas. This makes a rather inflexible condition, however, wherein the forehearth channel once put on oil had better remain on oil.

Courtesy, Thatcher Glass Mfg. Co., Elmira, N. Y.

Fig. 16. Radiant tube burner in operation.

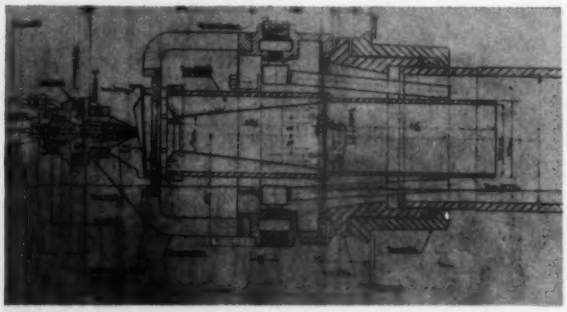
Decorating lehrs in present sizes are fair sized users of fuel. Most of those designed for normal use on natural gas are not suitable for firing with No. 2 oil direct, except by intermediate use of an oil-vapor gas generator. The ideal solution to this problem lies in radiant tubes, in which each tube represents an individual fire box, and the switch from gas to oil or vice versa can be made readily. The principle employed is exhibited in Figure 15A in an early type of installation. The flame tip is usually held to a point just past the bend, however, and an exhaust fan is employed in place of the educator. Tubes may be "U" or "W" in shape.

A burner which has proved very satisfactory is shown in Figures 15B and 16. Compressed air at about 10 p.s.i.g. introduced through the atomizer at the left induces oil from a small graduated gravity pot alongside and blows it through the refractory ignition block. A spark plug on the side of the alloy tube extending from the refractory block provides the ignition. The spark re-



Courtesy, Surface Combustion Corp., Toledo, Ohio

Fig. 15A. Radiant tube.



Courtesy, Surface Combustion Corp., Toledo, Ohio

Fig. 15B. Radiant tube, combination burner for firing oil or natural gas.

Courtesy, Thatcher Glass Mfg. Co., Elmira, N. Y.

Fig. 17. Surface Combustion radiant tube "Pyroglaze" lehr firing oil or natural gas.

mains on at all times. The tube itself is, of course, under suction from the exhaust fan. Secondary air is sucked in around the burner tube. Suction is controlled by a slide damper on the exit of the radiant tube. It is usual to carry about 3% free oxygen in the off-gas to avoid carbon formation (which is loose) in the fore end of the tube. On natural gas, compressed air and oil are cut off and a small stream of gas comes through the atomizer to act as a pilot. The main stream under 2-3 lbs. pressure comes through the annular space in the burner casting and issues through the tubular jets shown outside the alloy center tube.

Figure 17 shows a 6′ x 130′ Surface Combustion Radiant tube decorating lehr which operates continuously at heavy load, "Pyroglazing" Thatcher quart milk bottles. The temperature control is automatic, and operated by two control assemblies like the one shown in Figure 18. The control is dual, controlling either the compressed air for atomization in the case of oil, or the gas itself in the case of natural gas.

At first in these installations the tube spacings were very accurately designed but in subsequent designs when the potentialities had become apparent, tubes were laid in almost every way possible to get them in, even to the point of tipping them up (Figure 19). Proportioning control does not work well with radiant tubes on account of the fact that temperature distribution varies with changing flame length. The control is therefore high-low, which actually gives very close control because of the low heat capacity in the lehr structures itself. The amount of refractory materials is very small and the rate of heat-up and cool-off is accordingly quite rapid.

Courtesy, Thatcher Glass Mfg. Co., Elmira, N. Y.

Fig. 18. Dual automatic control mechanism.

Courtesy, Thatcher Glass Mfg. Co., Olean, N. Y.

Fig. 19. Radiant tubes in Surface Combustion "Pyroglaze" lehr.

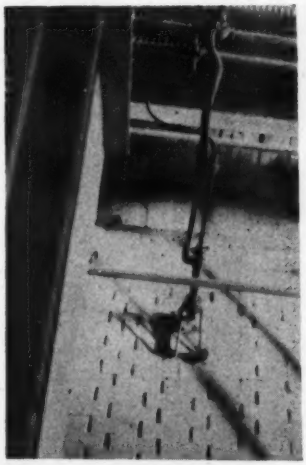
Courtesy, Thatcher Glass Mfg. Co., Elmira, N. Y.

Fig. 20. Natural gas piping for glass furnace.

Melting Fuel

On a dollar volume basis, of course, the use of fuel on glass furnaces themselves is by far the most important. However, it is a little better off, if anything, in this regard since natural gas is a little more easily replaced in this case.

Generally speaking, hot producer gas from bituminous coal is at one and the same time the most satisfactory and the most economical substitute, at least within reasonable shipping distance of the coal fields. However, even with producer gas it is necessary to provide an alternate. It is not feasible to accumulate a coal pile big enough to run indefinitely, if for no other reason than the deterioration of the coal itself. Also, good producer coal is becoming more scarce, which means that chances for poor producer operation are greater than was previously the case. Also, bituminous producer gas piping has to be blown or burned out at intervals of two or three weeks, in which period the producer gas is interrupted for a period of three to four hours. Previously this was done with the gas log drawing through the furnace stack itself but now with the provision of a separate burnout stack for the producer piping, the operation of the furnace can proceed without interruption on an alternate fuel.



Courtesy, Thatcher Glass Mfg. Co., Elmira, N. Y.

Fig. 21. Crown oil burner.

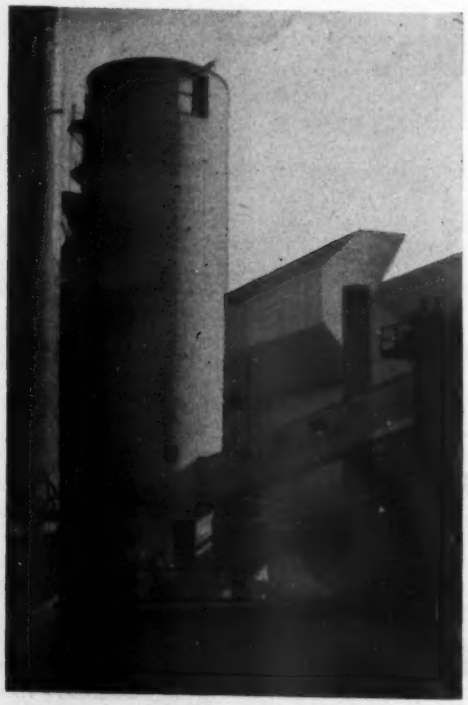
Figure 20 shows a typical furnace setup for firing with all three fuels: Producer Gas, No. 2 oil, and Natural Gas. Producer gas is its normal fuel. No. 6 or Heavy Fuel Oil has been discarded entirely from this system. Cocks for adjustment of port fires through the natural gas burners are located at the end of the port within handy reach. No. 2 oil when used is applied through the crown as shown in Figure 21. Both high pressure air and oil are

Courtesy, Thatcher Glass Mfg. Co., Elmira, N. Y.

Fig. 22. Crown oil burner.

supplied to the furnace under fairly close pressure control conditions. No preheating nor recirculation is required, of course. The burner opening block is set in the center line of each port, at a position about 2′ out from the arch such that the flame strikes down on the surface of the glass at a point about 5 feet out from the side wall. The flame of this type is soft and radiant. It actually pours over the glass instead of "striking" it. Actually it is a more effective flame for fast melting than is either of the gas flames. Sometimes when a furnace gets old and in bad condition, the No. 2 oil is applied as a booster to the gas.

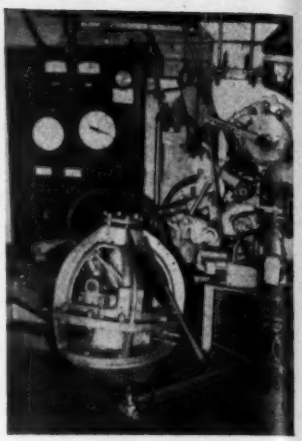
Heavy oil (No. 6) has been applied through the crown in the same fashion as shown in Figure 22. This was taken after the furnace went down and things looked fairly well battered up. In this case the burner is of the low pressure atomizing type which gives a soft, radiant fire.



Courtesy, Thatcher Glass Mfg. Co., Elmira, N. Y.

Fig. 23. New bituminous gas producer plant.

Producer gas generation, however, is more or less the answer right now, practically speaking, and in Figure 23 is shown a new bituminous producer plant recently started up in the Elmira, N. Y., plant of Thatcher Company. The tall silo contains both the live storage coal and the producer itself. Coal is unloaded under the track through a crusher and is conveyed to the basement under the silo from which point it is transferred to the top by means of a drag conveyor inside the silo wall, which travels up one side and down the other. The coal passes over an inclined screen, the fines dropping into a separate storage compartment, and the coarse into a lowering device (Helix) which lets it down into the bin with a minimum of breakage. The fines are released through the chute in the front which has a suspended extension for loading a truck.

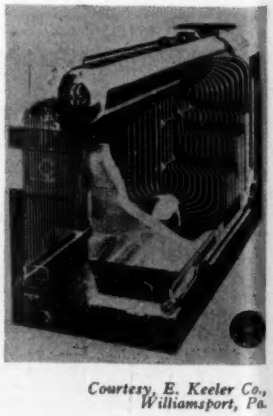


Co., Elmira, N. Y.

Fig. 24. Operating floor new bituminous gas producer plant.

The operating floor of the producer is at the same level as the furnace floor behind it. The producer itself is a Wellman (11 foot) water-jacketed type without a brick lining, although the gas log and dust catcher (not visible) are, of course, brick-lined. Exhaust fans just under the live load floor keep the producer floor ventilated. The ashes plowed out of the pan are elevated to the small tile ash bin on the side of the silo. An existing gas plant, built about 1940 and comprising a pair of producers, lies to the right hand side of Figure 23. It also is supplied with coal from the new silo via the inclined conveyor housing. Coal unloading capacity is such that a car of coal can be unloaded in an hour, counting the time required to move the car in and out.

The elimination of fines is probably of more benefit to good producer operation than almost any other one thing, as has been recognized for a long time. This is particularly noticeable in coal that has been stored for some time on the ground, and in producers which are being pushed to the limit. However, the removal of fines from ¾″ down to dust, introduces a new problem — namely, what to do with the fines. Fortunately a producer plant requires steam and the boiler house in a glass factory offers the only point of refuge.



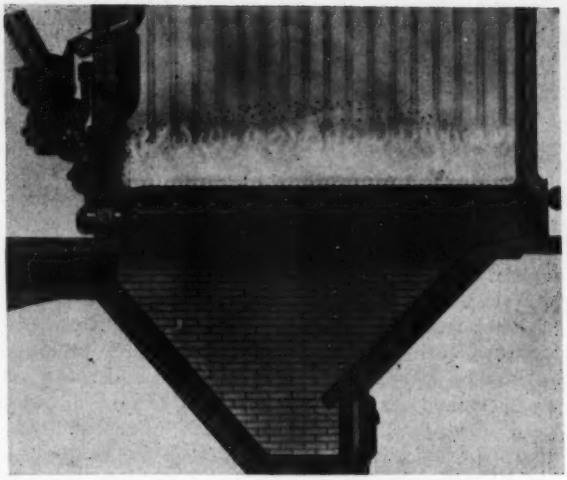
Courtesy, E. Keeler Co., Williamsport, Pa.

Fig. 25. Phantom view of underfeed stoker in new water-tube boiler.

Although producer coal

is high BTU coal, it is not especially good for boiler stokers in that its high volatile matter requires plenty of over-fire ventilation to ensure clean firing. The most common type of stoker in use in medium sized boilers of about 200-450 H.P., which is about the size of most concern to glass plants, is the underfeed type (see Figure 25) in which the coal is rammed up from beneath the incandescent bed. The distillation products from the green coal are compelled to pass through the fire before being released from the fuel bed. Even though this is an admirable stoker and is capable of handling a greater variety of coal than almost any other type, it does ont suit this case too well in that it will not take a feed of 100% fines. It has been claimed to be able to handle a blend of up to 90% fines under ideal conditions but it appears that with producer coal at least, a maximum of about 65% is all that is attainable. With excess of fines, of course, the fire has a tendency to form a plastic mass, making it difficult to get updraft air to pass through the cake, without the formation of blow holes.

The best type of stoker for a condition of this kind is the spreader type shown in Figure 26, which is designed to handle fine grades of coal only. In this type, the coal feed is kicked out over the flat grate which forms the floor of the fire box. The finest material is burned in suspension in air while the depth of fuel bed itself on the grate is never more than a few inches. The same boiler fitted with a spreader stoker instead of the underfeed type will have much more rapid steaming acceleration also; and is capable, with the type of boiler shown, of picking up a load of 200% rating, starting from somewhere around 50%, in a matter of five minutes or less. With this type of stoker it is possible to burn 100% fines and thereby keep the rejected producer fines about in balance with the boiler fuel requirements.



Courtesy, Hoffman Combustion Engineering Co., Detroit, Mich, and E. Keeler Co., Williamsport, Pa.

Fig. 26. Spreader Stoker.

Coal

For the United States as a whole approximately as much of the total generated and harnessed energy comes from coal itself as from all the other sources combined, roughly as follows:

Source	Per Cent
Coal	50
Petroleum	30
Natural gas	10
Hydroelectric power	10

Samuel W. Parr[11] at the University of Illinois originally observed on the basis of thousands of samples that mineral matter (Mm) had little if any relation to the rank of coal; also that moisture in coal is an extraneous variable. In other words, ash and moisture both are extraneous variables peculiar to the locality or mine and independent of the "pure" coal itself. The remainder is the dry, mineral-matter-free, pure or unit coal, in which fixed carbon and volatile matter add up to 100%. Out of this grew the A.S.T.M. classification D 388-38, which the writer has pictured in graphical form in Figure 27.

High rank was well distinguished by either volatile matter or fixed carbon; low rank according to per cent of inert or non-heating volatile material which is related directly to oxygen content and inversely to heating value.

The routine analysis of coal generally consists of the "proximate" which includes, 1) Moisture given off by a 1 Gm. air-dried sample at 105° C. for 1 hour. 2) Volatile matter or the loss in weight of 1 Gm. heated in a covered crucible at 950° C. for 7 minutes with moisture deducted. 3) Ash, the residue which remains after all the combustible is burned out in a muffle furnace at 700-750° C., and 4) Fixed carbon, what remains.

The appearance and physical properties of coal are but vaguely related to its chemical analysis. Peat is not regarded as coal. Brown coal is the lowest in rank and is identified by its color and soft woody structure which disintegrates on drying. Lignite may be a dark brown or black, with either a woody or amorphous texture. On weathering it tends to break into slabs. Brown coal and lignite contain high moisture and even higher percentages of total oxygen. Black lignites grade off into sub-bituminous coals of lower oxygen content and correspondingly higher heating value.

Sub-bituminous coals cannot be distinguished as a class by appearance nor physical properties and are merely intermediate between black lignite and bituminous products. The oxygen content is always high and they "weather" or disintegrate on exposure. Bituminous coals vary widely in appearance, physical and chemical properties. They are intermediate in hardness between sub-bituminous and anthracite and generally exhibit a cubical fracture. At the top of the rank, anthracite usually has an amorphous texture and a conchodial fracture.

The only important workings of anthracite are at pres-

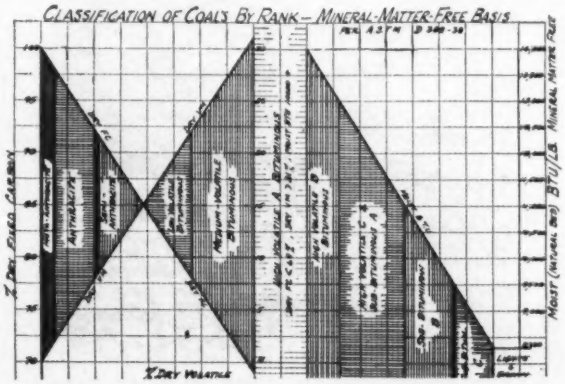


Fig. 27.

ent in the northeastern part of Pennsylvania and in parts of the British Isles. China and Russia also have workable deposits. Although the greatest tonnage mined is of bituminous rank, the most valuable is the domestic sizes of anthracite and due to its hard and tough nature the preparation of anthracite is usually far more extensive. The usual plant has many breaking, screening and cleaning units to handle simultaneously the various sizes. Slate and "bone" are picked out by hand on the conveyor, followed by a preliminary screening, picking or mechanical tabling. The larger pieces are broken in toothed rolls and put through a series of screens and washed in a jig or up-current classifier which removes slate and other high density impurities. The amount of fines produced is extensive in order to get the prized domestic sizes and may amount to as much as 25 or 30% of the coal processed. The amount of slate and ash appearing in the fines, of course, is greater than that in the lump sizes, which is true generally:

TABLE 1

Screen Sizes of Anthracite

Size	Passes Through	Retained On
Broken	4-7/16"	3-7/16"
Egg	3-7/16"	2-8/16"
Stove	2-8/16"	1-9/16"
Chestnut	1-9/16"	11/16"
Pea	12/16"	8/16"
No. 1 Buckwheat	9/16"	5/16"
No. 2 Buckwheat (Rice)	5/16"	3/16"
No. 3 Buckwheat (Barley)	3/16"	3/32"

The ash content may run, as an example, from about 5% on the egg size to as much as 16 or 17% on the buckwheat. There are mountainous piles of anthracite culm accumulated through the years in the anthracite fields.

Bituminous coal is much more friable than anthracite and breaking operations produce too much unwanted fines. Much of it is sold as "run of mine," including everything from large lumps down to fines. Preparation often comprises nothing but hand picking and screen sizing directly over the mine shaft. Cleaning is practiced extensively at many mines, however, wherein the ash content is reduced and with it much of the sulfur. In general the cleaning is accomplished through difference in specific gravity of the coal and the impurities in water suspension. The size classification of prepared bituminous coals varies by states and localities, and with the character of the coal. Illinois and Virginia have fairly well standardized sizes, however, which serve for purposes of comparison in Table 2:

TABLE 2

Dominant Prepared Sizes of Coal Shipped for General Domestic and Industrial Use

	Virginia[10]	Illinois[9]	
Lump	6"	6"	Lump
Egg	6 x 2½	6 x 3	Furnace (Egg)
		6 x 1¼	Egg and nut
Stove	3 x 1¼	3 x 2	Small egg
Nut	2 x ¾	2 x 1½	Stove (Range)
Stoker	1¼ x ⅝	¾ x 5/16	Small nut (Pea)
Mine Run	8 x 0	4 x 0	Mine run
Resultants	5 x 0	1½ x 28M	Modified Screenings
Screenings	1¼ x 0	1¼ x 0	Screenings
		7/16 x 10M	Dedusted slack
		5/16 x 0	Carbon (Slack)

The big problem insofar as bituminous producer operation is concerned lies in what constitutes good producer coal. This has never been defined really and perhaps is incapable of exact evaluation. The specifications given by Wellman,[14] for example, are very broad; viz., volatile matter 30-50%; Fixed carbon 50-60%; Ash, under 15%; Ash fusion temperature over 2200° F.; and all coal through a 4" ring. The reason for such broad classification is that almost any coal will make gas—it is mostly a question of gasification rate and gas quality on a producer under high load.

Returning to Figure 27, it will be noted that the classification beginning at one side with Meta-Anthracite ends with Medium Volatile Bituminous at 69% fixed carbon and 31% dry volatile matter. On the other hand, the classification starting with Sub-bituminous at 8300 moist, Mm-free BTU/Lb., ends with High Volatile B Bituminous at 14,000 BTU. In between lies High Volatile A Bituminous having dry fixed carbon less than 69%, dry volatile matter greater than 31%, and moist BTU greater than 14,000, all on a Mm-free basis. Good producer coals all lie in the High Volatile A classification, or close to it at any rate, in the High Volatile B. Good coking coals, on the other hand, which are certainly not desired in the producer, lie mostly in the Medium Volatile Bituminous class, although all bituminous coals apparently cake or coke to some extent.

Given a coal in the High Volatile A Class, it appears that the most important quality as far as good producer operation is concerned is the amount of ash contained in it, more important even than its ash fusion temperature. In the test data contained in Table 3, it will be

TABLE 3

Producer Performance Rating on Various Penna. and W. Va. Gas Coal Shipments—April-May 1947

Two (2) Wellman Engineering Type L-10 Brick Lined Producers
Average Coal through-put = 87 T/D
Mineral Matter Free Basis

Sample No.		Dry Fixed Carbon	Dry Volatile Matter	Moist BTU	Producer Performance Rating	ASH %	ASH Fusion
7	4" x 1¼"	57.5%	42.6%	14,100	(Good)	7.72	2270
9	2" x 1¼"	59.0	41.0	14,850	(Very Bad)	13.02	2490
4	2" x 1"	58.5	41.5	14,620	(Bad)	10.60	2280
3	2" x ¾"	58.5	41.6	15,500	(Very Bad)	13.29	2310
1	3" x 1¼"	52.6	48.9	16,600	(Very Bad)	16.45	2300
2	Fines	58.9	41.2	13,500	(Bad)	7.79	2480
5	2" x 1¼"	58.5	41.5	14,600	(Very Bad)	14.89	2310
X	6" x 2½"	59.3	40.7	14,850	(Best)	5.94	2295
XX	2⅛" x 1¼"	60.0	40.0	14,850	(Best)	6.70	2560

noted that of the numbered samples the one which gave the best operation was actually the one of lowest fusion point and that the most important quality was a low ash content. All are virtually the same coal on a dry, Mm-free, pure coal basis although their proximate determinations on an "as received" basis varied widely and in physical appearance these coals scarcely bore any resemblance to one another.

The effect of a high ash coal seems to be tied up with slowness of reaction rate, the fire bed thickens and even-

(*Continued on page* 412)

FIRST SYMPOSIUM ON CRYSTAL CHEMISTRY HELD AT RUTGERS UNIVERSITY

At the request of many ceramic technical men for a clarification of the role played by crystal chemistry in ceramics, a symposium on crystal chemistry was organized by Rutgers University and was held on June 4 in New Brunswick, N. J. Two of the six papers presented dealt with glass exclusively while some of the discussions throughout the session referred to the structure of glass. Dr. John H. Koenig, Director, and Dr. Charles H. Moore, Jr., National Lead Company and Visiting Professor, both of the School of Ceramics at Rutgers, were the chief organizers of this event which attracted over one hundred participants from all areas of the east. These men represented in equal proportions the interests of the Divisions of the American Ceramic Society. The Vice-President of the Society, H. M. Kramer, was welcomed cordially as its representative. It was the unanimous decision of the meeting to continue sessions on crystal chemistry. The University will distribute the papers presented in mimeographed or, if possible, in printed form.

Dr. Nelson W. Taylor, Assistant Director of Research, Minnesota Mining and Manufacturing Company, read an extensive introductory paper in which he had, together with Dr. William Lispscomb of the University of Minnesota, incorporated the essentials of crystal chemistry since V. Goldschmidt. Crystal chemistry has supplemented the findings of classical chemistry by the important emphasis of structure over composition. The discovery of X-ray and the genius of Dr. Goldschmidt, whose ardent disciple Dr. Taylor was, have cooperated in the fertile interpretation of properties. The distances between and the geometrical arrangements of particles of known charges rather than the formation of individual compounds predestine ceramic properties. Dr. Taylor also introduced the most recent concepts on chemical bonds in inorganic substances according to Lewis and Pauling.

The discourse of Dr. Taylor enabled those presenting specific papers to enter their own domain without lengthy introductions.

Glass and Crystal Chemistry

N. J. Kreidl, Bausch and Lomb Optical Co., Rochester, N. Y., presented a progress report on the application of crystal chemistry and related branches of theoretical chemistry to structural problems in the field of glass. The emphasis was on the less known methods used in the past five years.

The current network theory of glass formation explains sufficiently the single oxide glasses like SiO_2 and the glasses containing as modifiers noble gas type ions of small charge and large size (Na^+, Ca^{2+}).

The following additional problems of structure were discussed: 1) The observation of intermediate structural functions of cations such as Be^{2+}, Al^{3+} (Sun and Silverman). 2) The non-linear but continuous run of most properties near minima of liquidus of corresponding crystalline systems. 3) The transformation of the structure at medium viscosities. 4) The existence of vitreous orthosilicates containing SiO_4 islands.

The following recent methods applied to these problems were treated: 1) The evaluation of numbers to represent potentials or forces around constituent particles (Dietzel, Pincus, etc.). 2) The limited additivity of density increments per oxygen (Huggins, Stevels etc.). 3) The significant deviations of density and expansion increments (Stanworth). 4) The correlation of glass formation and energy of formation per coordination neighbor (Sun). 5) The rates of transformation (Winter-Klein, Lillie, McMaster, Collyer, Brandt etc.). 6) The heat evolution during transformation (Tool, Biels). 7) The molar refraction (Fajans-Kreidl, Stevels, Kordes).

The consideration of optical properties such as refraction and of density leads to the concept that electronic systems as well as atomic volumes are strongly affected by neighbors and that the measurements of the effect in terms of decreased molar refraction and molar volume show a continuous series of quantities related to glass formation. Generally, the quantitative evaluation can be limited to oxygen. However, in lead glasses the effect upon Pb^{2+} is the chief factor and the concept of an assymetrical electron. Distribution in lead explains the vitrification and properties of extreme lead glasses. The transformation of glass is considered a general case of order-disorder transformations in solids and the interesting transitional case of the feldspars (Barth) was demonstrated.

W. A. Weyl, State College, Pennsylvania, in the third paper of the session, applied the concept of assymetrical forces in glasses containing non-noble gas ions to surface phenomena and elaborated upon unusual effects of such surfaces.

The assymetry of Pb^{2+} in glass may be symbolized by comparing the one side having less electrons to Pb^{4+}, the other "metallic" side to Pb°. On surfaces the "metallic" layer is directed towards the outside.

In this way Weyl explains experimental facts such as: 1) The surface tension of lead glasses increases with temperature—normally the reverse is true—because the orientated layer is disturbed (Shartsis, Spinner, Smock). 2) Tl^+, Pb^{2+}, Sn^{2+}, Bi^{3+}, Sb^3 increase solubility for metals and adherence to metals (Marboe, Smiley and Weyl). 3) Hygroscopicity—as defined by Hubbard, NBS—is decreased by admixture or adsorption of lead (Roman, Marboe, Weyl). 4) Friction—determined by friction electricity or flow of beads in hour glasses—decreases with adsorption of lead. 5) Flex strength of lead-impregnated fibers is superior (Hyde). 6) The catalytic action of glasses containing or absorbing lead is low (Morlok-Weyl). 7) The release of gas bubbles from saturated solutions by glass surfaces having adsorbed or containing lead is high (Marboe and Weyl).

Other Ceramic Fields

Dr. S. O. Morgan, Bell Telephone, gave a beautiful demonstration in space of the building principles of

(*Continued on page* 412)

BORIC OXIDE–ITS CHEMISTRY AND ROLE IN GLASS TECHNOLOGY

By W. A. WEYL

The Pennsylvania State College, State College, Pa.

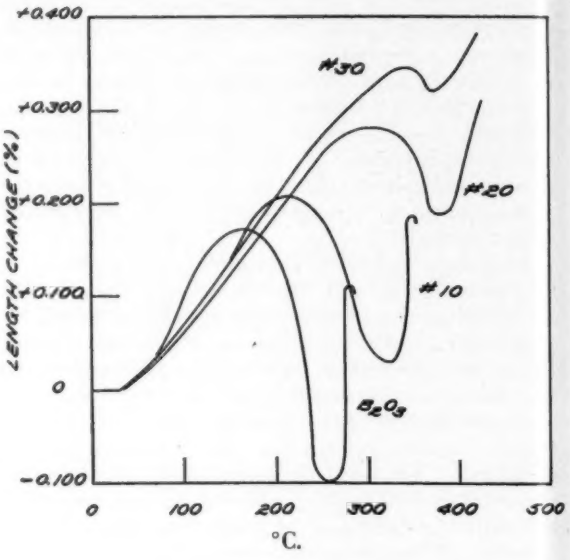
PART V

3. Thermal Expansion. Most of the boric acid which is consumed by the glass industry is used for lowering the thermal expansion or for improving related properties such as the resistance of glass to thermal shock. In spite of its great practical interest a theory of thermal expansion has not yet been developed, at least not to an extent that it could be used for interpreting or predicting thermal expansion. Surface tension and electrical conductivity have been explained by molecular pictures. Even if it was not possible to accurately predict the influence of certain oxides on the electric conductivity of a glass, the basic facts of this property are well understood. Unfortunately this is not true for thermal expansion. Even for a crystalline material of the simplest structure such as NaCl no explanation has yet been offered for its volume increase on heating. For two isolated ions of opposite charge it is possible to calculate the change of internuclear distance with increasing thermal vibration. The fact that the ions oscillate around equilibrium positions in an asymmetrical electric field, where the attraction forces decrease much less with increasing distance than the repulsive forces, accounts for the change of their distance with increased amplitude of vibration. From this simple model to a crystal or a glass is still a big step. All we can say about expansion is that it is not the amplitude of the thermal vibration in itself which determines the change in length or volume but the symmetry of the field of force in which the units are oscillating. That an increase of thermal vibrations alone cannot account for the expansion of matter on heating, can be seen from the behavior of fused quartz or water, both of which in a certain low temperature region contract on heating. Apparently this region can be shifted towards room temperature if minor additions (TiO_2 or B_2O_3) are incorporated into the silica glass.

In spite of our ignorance of the reasons why most materials expand on heating, this property has greatly contributed to the understanding of the constitution of glass. The earliest thoughts concerning the structure of glasses were centered around their expansion properties. The observation that most glasses irrespective of their chemical compositions show a similar type of thermal expansion was responsible for coining the term "Fourth State of Aggregation" for the vitreous state of matter. Even more important were the observations of A. Q. Tool and later workers, who found that the thermal expansion of a glass is not only affected by its composition, but also by the previous thermal history of a glass.

The influence which the composition of a glass exerts on its thermal expansion has been expressed in a few empirical rules. The classical attempts of Winkelmann and Schott to calculate the expansion of a glass on an additive basis by means of attributing "factors" to each

FIGURE 7
THERMAL EXPANSION OF ANNEALED B_2O_3-K_2O GLASSES AFTER R. L. GREEN



oxide are well known. English, Turner, Gilard, Dubrul, Mayer and Havas improved this method by determining new factors for certain fields of glasses and enamels. The basic idea was, that each oxide contributes in its own characteristic way to the thermal expansion of the glass and it was assumed that this property is additive. High alkali glasses have high thermal expansion and consequently the factors of Na_2O and K_2O were large (41 and 39 respectively). Pure SiO_2 glass has a very low expansion and as a result its factor had to be small (0.5). This method seemed to be logical until boric oxide was introduced as a major glass constituent and its influence on the thermal expansion was examined. Boric oxide itself has a very high coefficient of expansion but according to its influence on the thermal properties Winkelman and Schott had to attribute to this oxide a factor which was about one tenth of that of silica. English and Turner as well as Gilard and Dubrul went even further and gave the B_2O_3 factor a negative value.

From the previous discussions concerning the atomic structure of boric oxide and borate glasses we know that the structure of vitreous or crystalline B_2O_3 consists of BO_3^{3-} triangles whereas in alkali silicates this oxide provides BO_4^{5-} groups which in their symmetry resemble the SiO_4^{4-} groups. One can express this effect by saying: Addition of boric acid to a soda-lime-silica-glass makes the glass structure more "silica like". As pointed out in

a previous chapter the participation of boron in the glass structure in form of BO_4 groups is limited. Above a certain concentration boron participates preferably in the form of BO_3 triangles, its natural coordination. The equilibrium between BO_3 and BO_4 groups depends upon the alkali content of the glass as well as its temperature and heat treatment.

Numerous attempts have been made of measuring the thermal expansion of pure B_2O_3. Like all other properties, thermal expansion is strongly affected by the water content of the sample. J. J. Donoghue and D. Hubbard give an accurate description of the difficulties involved in measuring the coefficient of thermal expansion of vitreous and crystalline B_2O_3. Because of the experimental difficulties they claim only qualitative character for their measurements. Their paper contains a discussion of the earlier values reported in literature. Water content as well as thermal history have a strong influence on the properties of B_2O_3 glass. The influence of the thermal history on the properties of a glass is most pronounced in borosilicates because depending on the heat treatment various equilibria between BO_3 triangles and BO_4 tetrahedra are frozen in.

R. L. Green studied the thermal expansion of potassium borate glasses in connection with the X-ray investigation of these glasses. His measurements provide a fine example for the profound influence of the thermal history on the expansion behavior of borates. Fig. 7 shows the changes in lengths of the unannealed glass fibers, as they were drawn from the melt. For pure B_2O_3 the fiber was found to expand to about 190°C; at this temperature a contraction starts so that the fiber again reaches its original length at 225°C. Contraction continues to 250°C where the fiber has now become shorter than it was at room temperature. From this temperature on, normal expansion is observed. The amount of contraction typical for the unannealed sample decreases with increasing K_2O content.

Fig. 8 and Fig. 9 give the thermal expansion curves of the annealed potassium borate glasses. The glass

TABLE IX

Glass Number	Expansion cm/cm/°C	Transformation Point °C	Softening Point °C
B_2O_3	15.93 x 16^{-6}	247	267
10	13.50 x "	325	350
15	12.14 x "	357	380
20	11.77 x "	408	435
25	11.75 x "	408	437
30	12.49 x "	415	442
40	16.03 x "	423	445

number gives the approximate K_2O content of these glasses in weight per cent. As the K_2O increases (No. 10 to No. 25) the expansion decreases. Beyond this composition, however, further addition of alkali causes

FIGURE 8
THERMAL EXPANSION OF ANNEALED B_2O_3-K_2O GLASSES AFTER R. L. GREEN

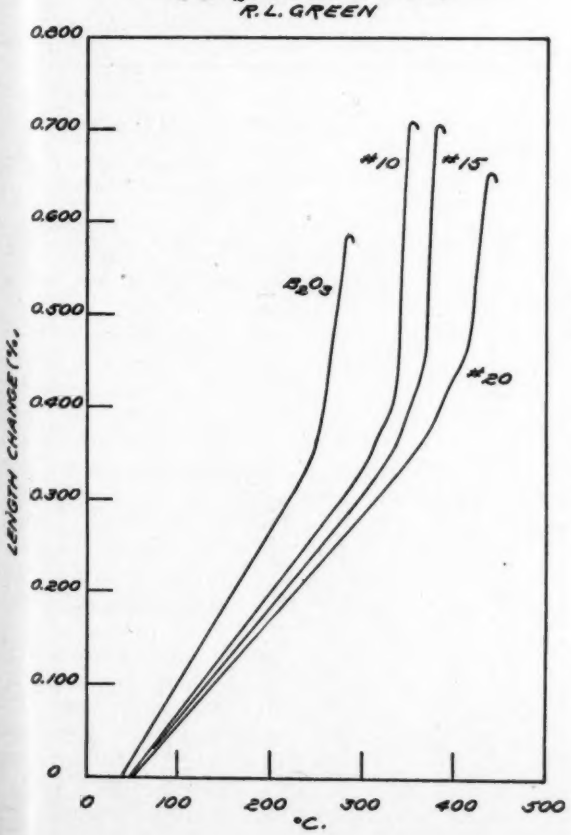
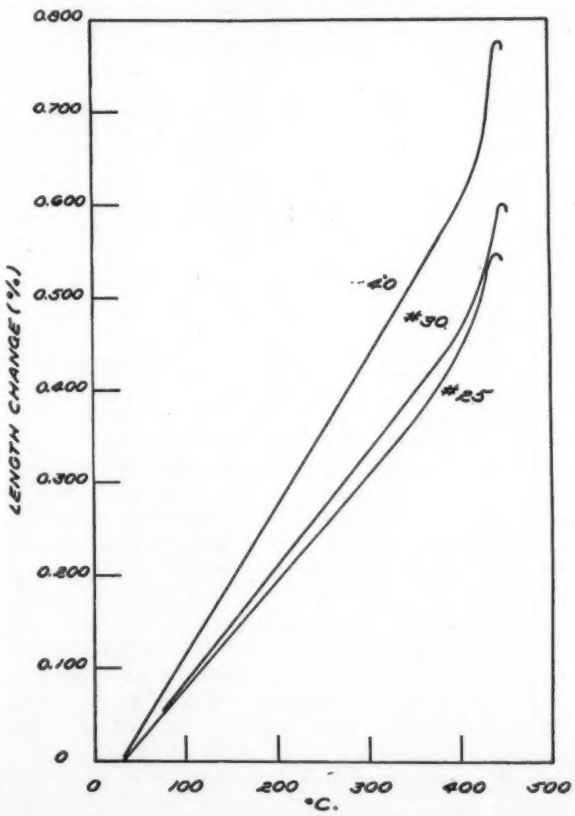


FIGURE 9
THERMAL EXPANSION OF ANNEALED B_2O_3-K_2O GLASSES AFTER R. L. GREEN



the expansion to increase (No. 30 and No. 40).

From these expansion curves R. L. Green derived the values for transformation and softening points as presented in Table IX.

In combination with the results of the X-ray investigation the expansion data were interpreted as follows. Vitreous B_2O_3 has the high thermal expansion which is characteristic for a structure containing BO_3 triangles. Addition of alkali first changes some of these boron atoms from threefold to fourfold coordination. This change which causes the glass structure to become more silica-like lowers the coefficient of thermal expansion. Above a certain alkali content, however, additional alkali does not merely affect the coordination of the boron but exerts a loosening effect upon the silica-like structure just as it does in alkali silicate glassses. Thermal expansion increases again. The two structural changes which the addition of alkali produces in borate glasses, namely changing BO_3 into BO_4 groups and loosening the structure of BO_4 tetrahedra causes the thermal expansion to go through a minimum value.

This structural change occurs whenever an alkali is added to B_2O_3 glass or whenever B_2O_3 is added to a glass containing a major amount of alkali. It is characteristic for sodium borate and sodium borosilicate glasses. However, if B_2O_3 is added to SiO_2 no such structural change can occur and as a result the coefficient of thermal expansion of vitreous SiO_2 is increased with increasing B_2O_3 content. The properties of SiO_2-B_2O_3 glasses are approximately additive, over a wide region as one can see from the values given by A. Cousen and W. E. S. Turner. (Table X)

Even the system SiO_2-B_2O_3 cannot be fully understood on the basis of additivity, because it seems that minor additions of B_2O_3 decrease the thermal expansion of an SiO_2 glass, at least in certain temperature regions. James B. Saunders who compared the expansivity of fused quartz with that of a Vycor brand glass (96% SiO_2 rest B_2O_3 with minor amounts of Na_2O and Al_2O_3) found that the latter at 700°C shows only half the expansivity of fused quartz. At 300°C the expansivities of the two glasses are equal and at room temperature Vycor has a coefficient of expansion which is twice that of fused quartz.

TABLE X

% SiO_2	% B_2O_3	$\alpha \times 10^7$
5.2	94.8	131.7
10.0	90.0	118.1
14.8	85.2	111.4
24.5	75.5	87.0
38.0	62.0	71.9
45.5	54.5	57.6
52.2	47.8	49.8
57.2	42.8	47.5

L. Grenet, as early as 1896, discovered that the thermal expansion of Na_2O-B_2O_3 glasses as a function of the composition goes through a minimum. It was not until 25 years later that the thermal expansion of alkali borosilicates was studied in a more systematic way. In England, through the efforts of W. E. S. Turner and his associates, and in Germany, through E. Zschimmer and his collaborators, several papers appeared during the years of 1921-1935 which present a complete picture of the thermal expansion behavior of glasses of the

(*Continued on page* 413)

TABLE XI

Values of Thermal Expasion Coefficients (x 10^6) for the Temperature Range 0-100° for all Glasses of the System Na_2O-SiO_2-B_2O_3

% B_2O_3	% SiO_2 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
100	15.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
95	12.7	13.4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
90	10.0	10.1	11.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
85	8.5	8.9	10.0	11.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
80	9.0	8.3	8.0	8.5	10.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
75	9.6	8.3	7.6	7.8	8.2	8.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
70	10.3	8.9	7.8	7.5	7.6	7.8	8.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...
65	...	9.7	8.5	7.7	7.3	7.3	7.3	7.3	...	...	...	...	...	...	...	...	...	...	...	...	...
60	...	...	9.8	8.1	7.4	7.0	6.7	6.6	6.7	...	...	...	...	...	...	...	...	...	...	...	...
55	...	...	...	9.3	8.1	7.6	7.0	6.4	5.9	6.0	...	...	...	...	...	...	...	...	...	...	...
50	...	...	...	11.3	9.9	8.4	7.6	6.7	5.9	5.4	5.4	...	...	...	...	...	...	...	...	...	...
45	...	...	...	...	11.7	10.2	8.7	7.8	6.9	5.9	4.9	4.8	...	...	...	...	...	...	...	...	...
40	...	...	...	...	...	13.6	10.1	9.3	8.2	6.9	5.7	4.8	4.3	...	...	...	...	...	...	...	...
35	...	...	...	...	...	...	13.0	11.7	10.2	8.5	6.7	5.5	4.6	3.8	...	...	...	...	...	...	...
30	...	...	...	...	...	...	...	11.8	10.7	9.5	8.2	6.6	5.3	4.2	3.3	...	...	...	...	...	...
25	...	...	...	...	...	...	...	12.2	11.9	11.0	10.1	8.1	6.6	5.2	4.0	2.9	...	...	...	...	...
20	...	...	...	...	...	...	...	...	13.4	12.7	11.7	10.1	8.0	7.1	4.9	3.4	2.4	...	...	...	...
15	...	...	...	...	...	...	...	...	...	14.2	12.9	11.6	10.1	8.4	6.9	5.3	3.6	1.9	...	...	...
10	...	...	...	...	...	...	...	...	...	15.1	14.0	13.1	11.9	10.5	8.2	6.7	5.0	3.1	1.5	...	...
5	...	...	...	...	...	...	...	...	...	...	15.3	14.7	13.8	12.3	10.4	8.4	6.8	5.0	3.3	1.0	...
0	...	...	...	...	...	...	...	...	...	...	17.7	17.0	15.75	14.0	12.3	10.6	9.1	7.7	5.0	2.75	0.5

INVENTIONS AND INVENTORS

A Summary of Recently Issued Patents of Interest to the Glass Industry

Feeding and Forming

Blow Head for Bottle machines. Fig. 1. Patent No. 2,442,315, This patent is the invention of Otto H. Samuelson and Anthony T. Zappia who assigned it to S. & Z. Manufacturing Company, Inc., of Indianapolis, Ind. This blow head provides for internal cooling which, as is well known, circulates cooling air in the bottle after it has been expanded by blowing pressure. Means is also provided for blowing cooling air on the finish. This patent relates back to two earlier patents by the same inventors, Nos. 2,363,999 and 2,382,028.

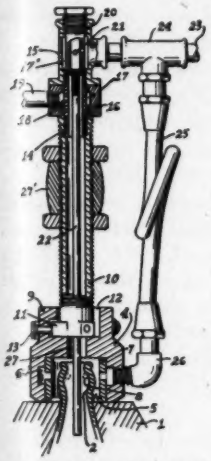


Fig. 1 Blow Head for Bottle Machines.

Figure 1 shows a blow mold 1 holding a blank having a finish 2. A blow head 4 rests on the top of the mold and the inside of the blow head has openings 8 which direct air against the finish of the bottle. The top of the blow head carries a neck 9 which supports a hollow stem 10 held in place by pins 13. There is a T-coupling 15 on the top of the stem and below that, there is a cooler 16 having an outlet pipe 19.

The T-coupling carries a nipple 20 having a long tube 22 which projects into the neck of the bottle. Air is supplied through a pipe 23 which also connects by a pipe 25 with the lower part of the blow head. The connections are such that when air is admitted through the pipe 23, it passes through the tube 22 to blow the bottle and at the same time air is blown against the finish to prevent it from bulging. The blowing and cooling air are controlled by a valve in the pipe 19 which does not show in the drawing. By this mechanism the parison is expanded to form the bottle and then cooling air is circulated inside the bottle and blown against the finish.

The following references are of record in the file of this patent: United States Patents: 2,123,145, Peiler, July 5, 1938. Foreign Patents: 310,421, Great Britain, Feb. 27, 1930.

Glass Compositions

Phosphate Glass. Patent No. 2,441,853. This patent was assigned to General Electric Company by John E. Stanworth of Sheffield, England. The invention relates particularly to soft glasses of high expansion coefficient and having better chemical durability than has formerly been possible.

The glass composition in percentage by weight is:

	Per cent
P_2O_5	28-38
Alumina	8-24
Boric oxide	0-20
Lead oxide	15-40
Sodium+potassium oxide	10-20

If the glass is to be used in sealing to copper, an expansion coefficient approaching that of copper may be had by using the following composition:

	Per cent
P_2O_5	33.5
Alumina	15.5
Boric oxide	7
Lead oxide	30
Sodium oxide	14

Patent No. 1,964,629 dated June 26, 1934 to Grimm et. al. was cited by the Patent Office during the prosecution of this application.

Amber Glass. Patent No. 2,443,142. This glass is the invention of Aaron K. Lyle of West Hartford, Conn., who assigned it to Hartford-Empire Company. The invention relates particularly to glass of the reduced or carbon-sulfur type.

Prior glasses of the reduced or carbon-sulfur type has been very unstable and difficult to melt. The glass was improved somewhat by the use of 0.20% or more of iron sulfide but the desired colors were difficult to obtain. The new glass is produced by the unexpected discovery of the effect of the relation between the alkali content and the silica content.

The newly discovered relation between alkali and silica referred to above is that these constituents are required to be present within the above approximate limits in such proportions that the percentage of silica by weight minus twice the percentage of alkali by weight equals K, a constant ranging in number from 45-60 inclusive. Stated otherwise, and letting S represent silica and N alkali, then

$$S-2N=K$$

K being a constant dependent upon the amounts of coloring agents used and having a value ranging from 45 to 60, inclusive.

Thus, with the same proportions of carbon and sulfur, K being 45 for example, the same color is obtained within the above limits of composition and in which the above described proportions of silica and alkali are present. By increasing K, the color intensity is increased and by decreasing K, the color intensity is decreased without changing the proportions of carbon or other reducing agent and sulfur or sulfur compound, used as coloring material. In this way, intensity of coloration may be controlled and stabilized through an unusually wide range and stability is maintained for surprisingly long periods of time.

Five examples of glass compositions and the corresponding batches according to this patent, are given in the following tables which also give the K-value:

TABLE I

Compositions of amber glass

Oxide	A	B	C	D	E
SiO_2	70.0	73.0	76.0	80.0	79.0
Al_2O_3	3.5	1.0	3.0	3.0	2.0
CaO	7.3	12.3	5.9	4.9	1.3
MgO	5.2	0.2	0.1	0.1	0.0
BaO	1.0	....	....	....	....
Na_2O, K_2O ..	12.0	13.0	14.0	10.0	17.0
B_2O_3	....	0.5	....	....	....
CaF_2	1.0	....	1.0	2.0	0.7
Fe_2O_3	0.041	0.052	0.041	0.035	0.027
K-value	46	47	48	60	45

TABLE II

Batches for amber glass compositions of Table I

Material	A	B	C	D	E
Sand	200.0	200.0	200.0	200.0	200.0
Soda ash	55.3	60.5	61.2	38.5	73.5
Limestone	....	64.3	31.8	25.0	6.3
Raw Dolomite	79.8	....	....	....	....
Nepheline Syenite.	48.8	....	35.0	35.0	23.2
Feldspar	....	12.3	....	....	....
Barytes	5.0	....	....	....	....
Borax	....	3.9	....	....	....
Fluorspar	3.5	....	3.0	5.9	2.0
Powdered Charcoal	1.0	0.6	0.8	0.8	0.8
Sulfur	....	0.8	1.0	1.0	1.0

The following references are of record in the file of this patent: United States Patents: 1,830,902, Hood, Nov. 10, 1931; 2,056,627, Smelt, Oct. 6, 1936; 2,303,779, West, Dec. 1, 1942; and 2,367,871, Kalsing et. al., Jan. 23, 1945. Foreign Patents: 142,393, Switzerland, 1930. Other References: S. R. Scholes, Modern Glass Practice (1937), page 47, Eitel et al., Giastechnische Tabellen (1932), pages 636 and 697.

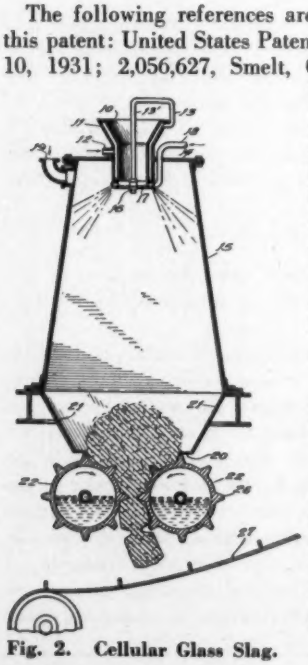


Fig. 2. Cellular Glass Slag.

Miscellaneous Processes

Cellular Glass Slag. Fig. 2 Patent No. 2,442,036. This method and apparatus for making expanded slag, was the invention of Wallace L. Caldwell of Birmingham, Ala. Glass is but one of the materials which may be treated by the same method.

It has been usual to make expanded slag by the use of water, steam, air or by mechanical means. These methods have generally been unsatisfactory mainly for the reason that the pores were not uniform in size. The apparatus shown in Fig. 2 produces masses of fine and uniform cell structure which may be used as an aggregate after the usual crushing and screening.

Glass or molten slag is introduced through a water cooled funnel 10 extending through the top 14 of an expansion chamber 15. When the glass leaves the funnel it is in the shape of a cylinder which immediately comes in contact with a high pressure jet of water from the nozzle 16. As the particles of expanded slag are thrown off by the nozzle 16, they are subjected to the action of high pressure steam, water or air from a ring 17. Any steam which may be evolved is taken off by a vent 19. The particles resulting from this treatment are deflected by plates 21 toward a discharge opening 20.

The character of the expanded mass is regulated by the rate of flow of the glass and the pressure of the blowing means. When the mass leaves the chamber, it is engaged by compressing rolls 22 which are water cooled and provided with ribs 26. These ribs form blocks of expanded material which drop onto a conveyor 27 where they slowly cool and are annealed. The blocks are then crushed for us as an aggregate.

The following references are of record in the file of this patent: United States Patents: 1,184,462, Larson, May 23, 1916, 1,458,858, Sem, June 12, 1923; 2,067,312, Coryell, Jan. 12, 1937; 2,118,707, Ingouf, May 24, 1938; 2,172,899, Barnard, Sept. 12, 1939; 2,236,691, Meinzer, Apr. 1, 1941; and 2,382,290, Callander, Aug. 14, 1945. Foreign Patents: 143,500, Great Britain, Apr. 7, 1921 and 227,848, Great Britain, Dec. 31, 1925.

Glass Bending Apparatus. Fig. 3. Patent No. 2,442,242. This patent was the invention of Joseph H. Lewis who assigned it to Blue Ridge Glass Corporation of Kingsport, Tenn.

In Fig. 3 there is shown a heating furnace 1 having a door 2 to permit flat glass sheets A^1, A^2, and A^3 to be placed on a silica hearth 3. A bending chamber 4 contains a fixed lower mold 5 and a movable upper mold 6, both the molds being heated by heaters 7. Fingers 8 and 9 at times form an extension of the hearth 3. A table 10 has a rib 11 which forms a stop to position

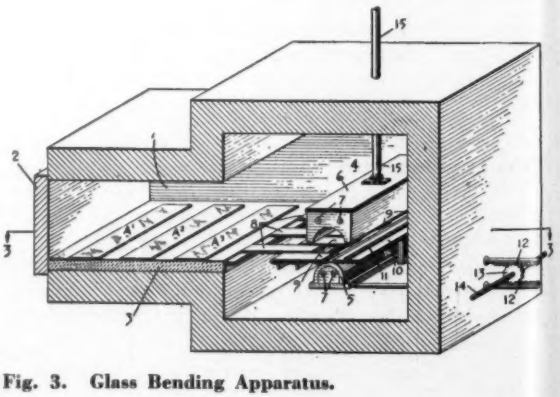


Fig. 3. Glass Bending Apparatus.

a sheet of glass in proper relation to the molds. The fingers 9 and the table 10 are moved toward and from the lower mold by a shaft 14 carrying a gear 13 in mesh with two racks 12.

In the use of this apparatus, the sheets are pushed into position between the molds, the fingers are withdrawn and the upper mold is brought down on the glass which has become soft by that time. The upper mold is then lifted and the curved sheet is pushed endwise off from the lower mold and in so moving, passes below a blast box which cools the glass so that it holds its shape.

The following references are of record in the file of this patent: United States Patents: 4,786, Paine, Oct. 3, 1846; 2,111,370, Owen, Mar. 15, 1938, 2,131,873, Goodwillie, Oct. 4, 1938; 2,223,124, Owen, Nov. 26, 1940; 2,247,118, Drake, June 24, 1941; 2,251,159, Owen, July 29, 1941; 2,369, 368, Paddock et al., Feb. 13, 1945; and 2,370,575, Owen, Feb. 27, 1945.

Machine for Molding Reflectors for Lamps. Fig. 4. Patent No. 2,442,860. This patent was assigned to Westinghouse Electric Corporation by Henry K. Richardson of Bloomfield, N. J.

Fig. 4 shows a lamp base or reflector portion 11 having lead wires 12, 13 and 14, and an exhaust tube 15. The inner surface 16 is later coated with light reflecting material such as metal. The lower die 20 is surrounded by a guide 19 and arranged to cooperate with the upper die 26 to form the reflector. A stream of molten glass is delivered to the lower die preferably by mechanism such as shown in Patent Nos. 2,031,083 or 2,190,296 while the temperature is controlled as disclosed in Patent No. 2,116,450. A continuous machine for making reflectors is to be found in Patent No. 2,393,265 which insures that exactly the right amount of glass will be delivered to each mold.

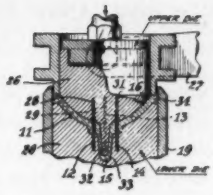


Fig. 4. Machine for Molding Reflectors for Lamps.

The upper die has openings 28, 29 and 31 to receive the lead wires and a projection 32 which forms the opening in the exhaust tube. After the glass has cooled sufficiently, the upper die is removed and the lower die is lifted within the guide 19 so that the reflector can be readily removed.

The following references are of record in the file of this patent: United States Patents: 235,522, Geyer, Dec. 14, 1850; 796,470, Swan, Aug. 8, 1905; 1,149,038, Ficq, Aug. 3, 1915; 1,606,276, Vello, Nov. 9, 1926; 1,660,649, Mailey, Feb. 26, 1928; 1,861,167, Vello, May 31, 1932; 1,965,408, Eden et al., July 3, 1934, 2,006,818, Zimber, July 2, 1935; 2,030,186, Rose, Feb. 11, 1936; 2,120,836, Grimes, June 14, 1938; 2,131,923, Thomas, Oct. 4, 1938; 2,134,551, Enfield, Oct. 25, 1938; 2,148,314, Wright, Feb. 21, 1939; 2,177,217, Howard et al., Oct. 24, 1939; 2,315,292, Richardson et al., Mar. 30, 1943; and 2,219,574, Fraenckel, Oct. 29, 1940. Foreign Patents: 12,015, Great Britain, 1887.

UNIVERSITY OF ILLINOIS GRADUATION

The University of Illinois Department of Ceramic Engineering conferred twenty-seven degrees at its recent graduation ceremonies. Of this total, twenty-one students received the B.S. degree in Ceramic Engineering.

In addition, the following students receiving degrees from the graduate college presented a thesis concerning glass: Stig Lindroth, M.S., "Glass Formation in the System CaO-Al_2O_3," and E. Miller, Ph.D., "Problems in the Specification of the State of Glass; Crystallization Phenomena".

During the past year, the Department of Ceramic Engineering has made many changes in existing facilities and added a great deal of new equipment for use in research and teaching. A new Phillips recording x-ray spectrometer has been purchased and is being installed. Many changes have been made in the kiln house. Two high temperature Remmey kilns and a controlled atmosphere kiln have been added. During the summer months, two "glo-bar" kilns of about five cubic feet capacity each will be built. These will be automatically controlled and recorded and are intended primarily for student research work. Equipment has been ordered to completely modernize the kiln house control equipment.

During the past year, two new laboratories have been built and one remodeled. The glass technology laboratory has installed new lighting and power facilities and a Remmey high temperature furnace has been installed for glass melting.

• The Fall Meeting of the Glass Division of the American Ceramic Society has been announced to take place on October 8 and 9, 1948 at Bedford Springs, Bedford, Pa.

GLASS COMMITTEE HOLDS MEETING

During the recent annual meeting of the American Ceramic Society, Committee C-14 on Glass and Glass Products held a meeting with 24 in attendance.

The formation of a proposed subcommittee on illuminating glass was deferred pending further information as to the extent of coverage in this field by a sectional committee under the procedure of the American Standards Association, now being organized.

A proposed test on abrasion resistance of glass and plastics is in process of formulation by the sectional committee for safety glass which, when completed, will be presented to Committee C-14 for consideration. The Subcommittee on Nomenclature and Definitions reported the completion by the American Ceramic Society Standards Subcommittee of a glossary on glass, including 15 definitions, these definitions to be submitted to Committee C-14 for adoption. Proposed methods of sampling cellular load and nonload bearing glass block were recommended for submittal to letter ballot of the committee.

Additional recommendations for committee action included a method of sampling of glass containers and three test methods on durability of glass. These methods will cover powdered glass, bottles attacked by water and bottles attacked by acid.

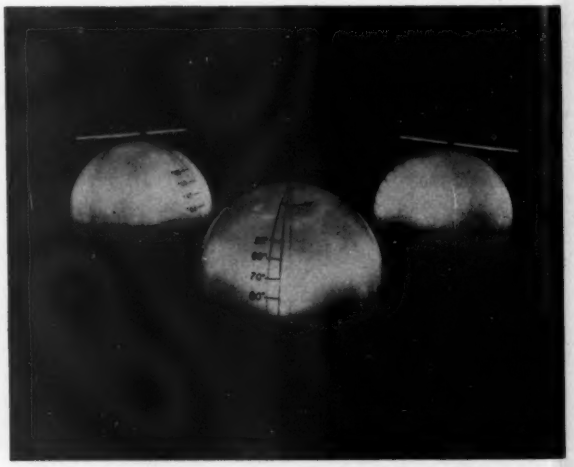
SYLVANIA ELECTRIC DEVELOPS QUALITY CONTROL DEVICE FOR MEASURING LIGHT DISTRIBUTION

A new time-saving quality control device has been developed by Sylvania Electric Products, Inc. which, they announce, allows engineers to make a fast appraisal of the light distribution of lens-type bulbs whose light distribution pattern is too wide to be measured on an ordinary projection screen. According to the company, use of this opal glass globe, or Inspectosphere, is not limited to this one type of light bulb, but can be employed for quality inspection on mass production lines or for small inspection jobs.

The Inspectosphere placed over a bulb, such as the street lamp shown in the photo at the top, enables a speedy appraisal of the direction and character of the principal light beams in the bulb. If any bulb, through improper location of the filament or improper alignment of the basing, does not meet the specifications for beam pattern, it can be detected easily and quickly by means of this test.

In the tests illustrated, a new type streetlight which employs prisms to direct light up and down the street was used and in order to record the complete distribution pattern of the light in one photograph, two mirrors were placed at angles behind the lamp.

The lamp under test in the photo at the lower left was found to give off a streaky pattern of light despite the fact that the principal beam was at an angle of about 72 degrees. If this lamp were put into use, the same lines on the globe would appear as streaks on the pavement. In the final step of the test, as shown in the lower right photograph, a lamp was used in which the streakiness was eliminated by use of greater diffusion, thus providing the desired smooth beam pattern with the maximum amount of light at 72 degrees.



COBALT OBTAINED FROM AMERICAN ORE BY ELECTROLYTIC METHOD

Cobalt can be obtained from the low-grade American ores by an electrolytic process which, as determined by a pilot plant of the U. S. Bureau of Mines, can be used commercially to obtain a good-quality cobalt at a cost far below current market quotations, according to Dr. James Boyd, Director of the Bureau.

Th investigation of cobalt production was carried out with ores from Idaho. Production methods include reducing the ore by roasting and acid leaching to purify the product. The final purification process is electrolytic.

A complete report on the technique is available at the U. S. Bureau of Mines, Washington, D. C.

FLAT GLASS AT PEAK PRODUCTION

Window glass production has been at a new peak so far this year but is still short of requirements, and plate glass has been running about 5 per cent above the same period in the record year of 1947, according to an announcement by John D. Biggers, President of Libbey-Owens-Ford Glass Company.

Labor conditions in the glass industry are on a sound basis of mutual understanding and cooperation between employee and management, Mr. Biggers further stated. Important technological improvements have been put into effect since the war which have helped to boost the output per man in the glass factories. Employment exceeds 10,000 workmen in Libbey-Owens-Ford Glass Company plants.

Research Digest

Electrically Conducting Glasses

Glasses, or objects made from glass, which have the property of conducting electricity, are rather new and offer many interesting possibilities. Green and Blodgett (*Journal of the American Ceramic Society*, April 1948) have recently reported on an investigation dealing with glasses having such properties. Inasmuch as the introduction to their paper contains much background that is valuable to those interested in this subject, it is repeated here in full along with the conclusions arrived at by the authors in their particular study.

"The flow of current through a glass by virtue of the movement of ions which, in part, constitute its structure has been studied intensively. It is known that the alkali ions are more readily transported than those of the alkaline earths and that the larger the effective ionic radius, the less the mobility. The electrical conductivities of glasses increase as the temperature is increased due to the greater ease with which the conducting ions can be moved when thermal agitation has weakened the forces binding them to the continuous networks of the glass structures. If alkali-containing glasses are heated to fluidity, electrolysis can be carried out and Faraday's law applies. Studies of the effects of the chemical composition of glass on the conduction behavior show that the introduction into an alkali silicate glass of ions such as those of lead or the alkaline earth metals, decreases the conductivities since these more firmly held ions obstruct the passageways in the glass networks through which the more mobile alkali ions must move. Introduction of boric oxide likewise decreases the conductivity since the alkali ions are held more securely due to the formation of BO_4 configurations.

"Numerous methods have been developed for increasing the conductivities of glassy materials by the application of highly conducting substances such as metals to the surfaces or in the bodies of glasses. In this manner, electronic conduction rather than ionic is involved and, consequently, the polarization accompanying the latter is avoided. Surface treatments for obtaining highly conductive layers include metallizing procedures wherein platinum, gold or copper salts are heated to reduction on the glass, vaporization of metals such as aluminum or antimony onto the surface, firing silver oxide or metal powder on with the aid of auxiliary fluxes, painting on lacquers containing flaky metals in suspension, and chemical treatments as are used in silver or copper mirror treatments. With these methods, control of the conductivity of the applied layer is not feasible as the insulating nature of the oxide surface will predominate up to the point where sufficient metal has been applied to give the surface the high conductivity of the metal itself. This means that the surface will be insulating as long as the metallic particles are not in contact and, when they are, conduction will be in the metal layer and will depend solely upon its properties. One method for rendering the surface of glass slightly conducting is to subject it to the vapors of stannic chloride. On hydrolyzing the deposited chloride, irridescent films of variable conductivity may be obtained. Another, which may be similar, is to treat the surface with $SiCl_4$ and then reduce the adsorbed layer.

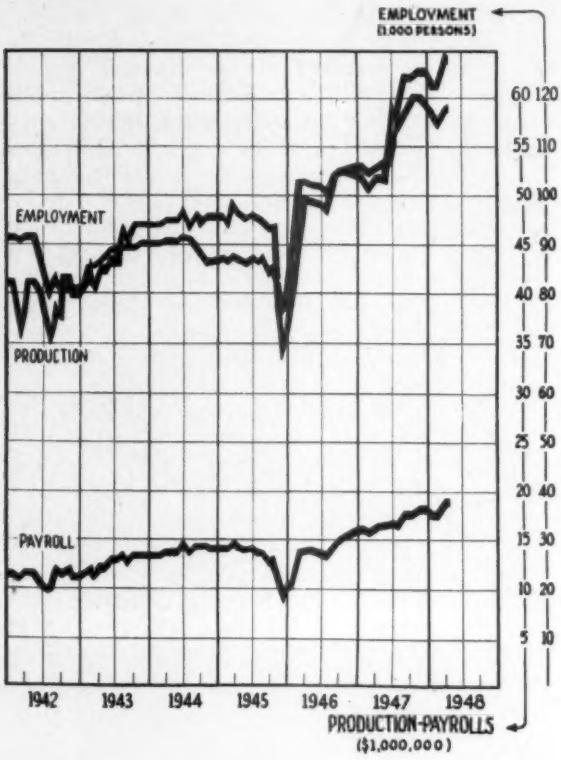
"A few methods have been developed for converting the body of a glass or glaze into a semiconductor or conductor. In one a mixture of a glass and semiconducting spinels is so fused that the crystalline spinel phase is continuous and the composite, accordingly, may be made conducting to variable and controllable extents. Mixtures of metals and oxides have been considered but here the limitations are similar to those considered in surface treatments. So long as the conducting particles are insulated from one another, the bulk conductivity will be that of the insulating phase, and vice versa. In a narrow range of proportions of the two constituents, the change in conductivity with change in composition is very rapid. Among the semiconductors developed in Germany, that made by the Rosenthal Porcelain Company is relevant here. A special low-melting glass is fritted and ground very fine. This is mixed with graphite in various proportions, sprayed onto porcelain and fused in the range 800° to 900°C. Resistors were made in two ranges, 50 to 100 ohms and 150 to 200 megohms. Here, resistivities are a function of the surface contacts of the graphite particles as in the case of mixtures of graphite and resins used for conducting coatings.

"The purpose of this investigation was to develop glasses and glazes whose conductivities over various ranges could be controlled accurately. It was, moreover, essential that the conducting layers should possess stable conduction up to high-voltage stresses, initial requirements being for surface resistances at the level of 10^9 ohms per square of area with ohmic conduction at voltage gradients up to 30 kv. per inch of length. In the work on this problem layers having resistances ranging from 20 to 10^{11} ohms per square were produced. In general, the principle employed was to incorporate into the glass structure, by melting, oxides which could be reduced readily to metals on heating in hydrogen. Initial work on glasses high in lead oxide content was extended to include others containing bismuth oxide and antimony oxide. It was well known that these oxides were readily incorporated into glasses and that they could be reduced subsequently. Previous usage of this method, however, was confined to artistic and decorative treatment although, more recently, this method has been used to gain further information on the chemical behavior of glasses. The advantage to the use of the oxides of lead, bismuth, and antimony is that relatively large percentages of these may be introduced and still enable the formation of uniform glasses. This feature permits the extension of the range of conduc-

(*Continued on page* 410)

CURRENT STATISTICAL POSITION OF GLASS

THE GLASS INDUSTRY'S INDEX



Activity in the glass industry for the month of April 1948, according to the Production Index, fell off close to 1 per cent to an estimated $64,500,000. Production during the previous month was $65,000,000. During April 1947, activity was estimated to be $58,000,000, which is about 11 per cent below April this year. For the January-April 1948 period, activity in the industry has reached an approximate $253,000,000, as compared with $226,500,000 reported for the corresponding months of 1947—a difference of about 11 per cent.

Employment and Payrolls: During the month of April 1948, employment in the glass industry rose only slightly from the 117,800 persons employed during March to a monthly figure of 117,900. Employment during the month of April 1947 was 104,000 persons.

Payrolls during April 1948 indicated very little change and remained at the estimated $18,500,000 reported for the previous month. Payrolls for April 1947 were an estimated $16,250,000, which is about 13 per cent below April this year. Thus far in 1948, glass manufacturers have paid out an approximate total of $72,000,000, as compared with $63,750,000 paid out during the same period in 1947.

Glass container production for the month of May 1948, based on figures released by the Bureau of Census, dropped slightly to a figure of 8,824,982 gross. This represents a decrease of about 1½ per cent from the 8,978,389 gross produced during the previous month. Production during May 1947 was 10,556,354 gross, or about 16 per cent above May this year. Total glass container production during the January-May 1948 period has reached a total of 42,045,946 gross, or about 19 per cent below the 51,938,175 gross produced during the corresponding months of 1947.

Shipments during May 1948 were reported at 8,198,417 gross, as compared with 7,811,641 gross shipped during April. This indicates a gain of close to 5 per cent for May. During May 1947, shipments were 9,889,718 gross, or 17 per cent above May this year. Shipments

(*Continued on page* 398)

GLASS CONTAINER SHIPMENTS

(All figures in gross)

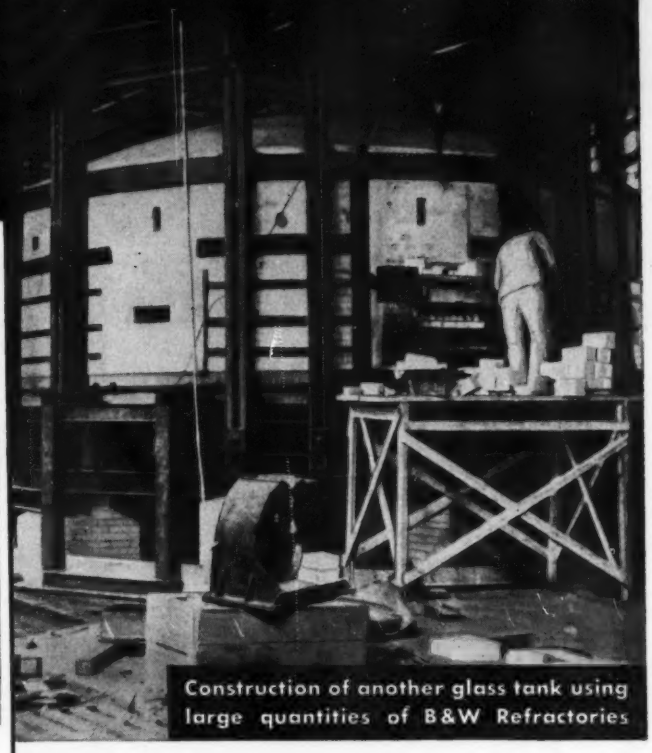
	May 1948
Narrow Neck Containers	
Foods	653,009
Medicinal & Health Supplies	880,420
Chemical, Household & Industrials	440,588
Beverages, Returnable	850,861
Beverages, Non-returnable	.....
Beer, Returnable	387,577
Beer, Non-returnable	304,678
Liquors	565,691
Wines	214,913
Toiletries & Cosmetics	338,486
Sub-Total (Narrow)	4,636,223
Wide Mouth Containers	
Foods	1,821,054
Dairy Products	209,967
Home Canning	568,133
Medicinal & Health Supplies	265,648
Chemical, Household & Industrials	96,268
Toiletries & Cosmetics	151,027
Packers' Tumblers	155,641
Sub-Total (Wide)	3,267,738
Total Domestic	7,903,961
Export Shipments	294,456
Total Shipments	8,198,417

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in gross)

		Production May 1948	*Stocks May* 1948
Foods; Medicinal & Health Supplies; Chemicals, Household, Industrials; Toiletries and Cosmetics	Narrow Neck	2,757,509	2,904,775
	Wide Mouth	2,593,062	2,202,893
Dairy Products		228,988	238,818
Home Canning		328,257	493,192
Beverages, Returnable		850,861	861,207
Beverages, Non-returnable		.....	.....
Beer, Returnable		387,577	872,572
Beer, Non-returnable		304,678	246,793
Liquors		565,691	321,456
Wines		214,913	208,525
Packers' Tumblers		170,281	72,619
Total		8,824,982	8,422,850

A Soaring Sales Curve Tells The Story



Construction of another glass tank using large quantities of B&W Refractories

When an engineer or a production man finds that B&W Refractories consistently outlast competitive brick, he's sold! When time comes to rebrick or expand, he's certain to specify "more of the same".

That is why B&W Sales to one typical glass manufacturer have mounted steadily year after year — from 1929, when B&W Refractories were first selected, to the present, when orders are larger than ever!

That is why more and more glass furnace operators throughout the country are trying — and then specifying — B&W Refractories (B&W 80 Firebrick, B&W Jr. Firebrick and B&W Insulating Firebrick).

Whether your installation is a pot furnace, tank or lehr, B&W Refractories will increase efficiency and reduce your production costs. Your local B&W representative is experienced in the application of refractories to glass furnaces. He will be glad to help you select the proper B&W Refractories for your job.

R-274

Water-Tube Boilers, for Stationary Power Plants, for Marine Service . . . Water-Cooled Furnaces . . . Superheaters . . . Economizers . . . Air Heaters . . . Pulverized-Coal Equipment . . . Chain-Grate Stokers . . . Oil, Gas and Multifuel Burners . . . Seamless and Welded Tubes and Pipe . . . Refractories . . . Process Equipment.

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CURRENT STATISTICS . . .

(*Continued from page* 396)

made during the first five months of 1948 have reached a total of 41,152,015 gross. This is about 16 per cent less than the 49,395,607 gross shipped during the same period in 1947.

Stocks on hand at the close of May 1948 were 8,422,850 gross, as compared with 7,866,639 gross on hand at the close of April and 6,085,635 gross on hand at the close of May 1947.

Plate glass production, according to the Hughes Statistical Bureau, was 20,782,870 sq. ft. for the month of May 1948. This figure represents a drop of about 11 per cent from the 23,416,518 sq. ft. produced during the previous month. During May 1947, plate glass production was 23,171,265 sq. ft., or about 11 per cent above May this year. Total plate glass production at the close of the first five months of 1948 has reached 111,480,401 sq. ft., as compared with 109,442,768 sq. ft. produced during the corresponding period in 1947. This represents a difference of about 1 per cent.

Automatic tumbler production for the month of May 1948 was 5,277,937 dozens. This is a decrease of close to 3 per cent from the 5,422,209 dozens produced during April. Production during May 1947 was 6,769,423 dozens. Shipments for May, 6 per cent below the 5,628,215 dozens shipped during April, were 5,277,119 dozens, and during May 1947, they were 6,234,240 dozens. Stocks on hand at the close of May 1948 were 8,398,385 dozens; at the close of April, 8,510,267 dozens; and at the close of May 1947, 6,671,992 dozens.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware for the month of May 1948 were 3,846,623 dozens which represents an increase of about 3½ per cent over the 3,713,799 dozens sold during the previous month. During May 1947, sales were 3,657,808 dozens. Total manufacturers' sales for the 12-month period of April 1947-May 1948 have reached 42,827,498 dozens, as compared with 44,429,834 dozens sold during the corresponding period in 1946-1947.

BRITISH GLASS REPORT

The British plate and sheet glass and glassware industries are making a successful attack on the targets set by the Board of Trade under the plan to expand exports. Plate and sheet glass exports in April 1948 amounted to £0.30 compared with £0.35 millions monthly over the first quarter of 1948. The aim of the Government for this industry by the end of 1948 is a monthly export of £0.44 millions.

Glassware exports rose to £0.35 during April as against £0.32 millions monthly during the first three months of 1948. The target for this industry is a monthly export by the end of the year of £0.46 millions. The targets set are regarded as being within the scope of the industry on its present showing, assuming that no factors develop in the intervening period to disrupt the flow of expanded exports.

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by break testing,

RAPIDLY
because there are no weights to handle,

ACCURATELY
as no increment factors are involved,

VISUALLY
with pressure indicated on gauge having reset pointer,

SAFELY
as the bottle breaks inside a metal shield,

with The TECO

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BOTTLE
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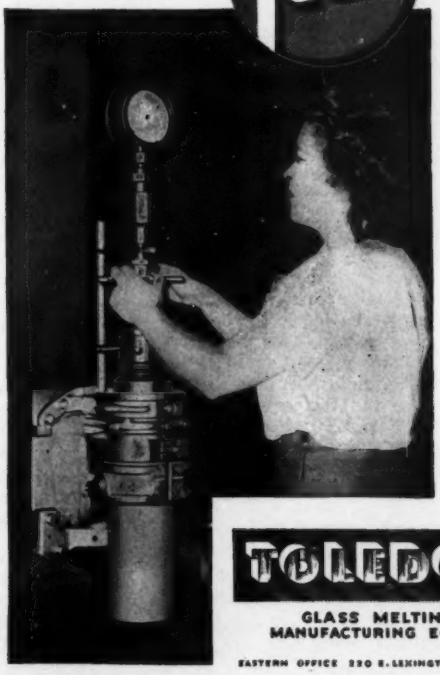

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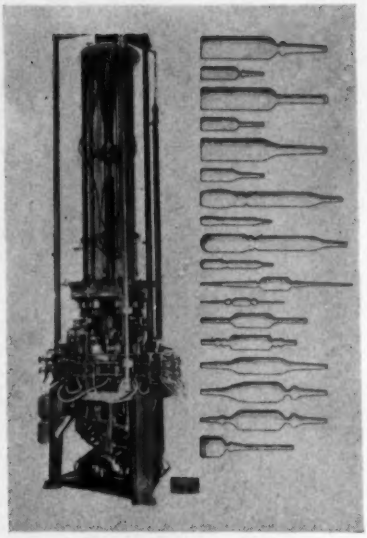
NEW EQUIPMENT AND SUPPLIES



AUTOMATIC AMPULE MACHINE

Kahle Engineering Company, 1313 Seventh Street, North Bergen, New Jersey, has announced a new automatic ampule machine employing the technique of partial or total blowing into a mold and using a variable-speed, dual drive motor.

This machine can produce ampules of every type and shape, standard and special, up to 2400 per hour, according to the company's report. The only necessary hand operation is the placing of the 5-foot lengths of tubing in the machine. All other operations of heating, molding and unloading are automatic.

The ampule machine has a synchronous lower turret with concentric heads, whereby both ends of the glass are held as in vertical lathes during stretching and molding. If desired, it can be operated without the mold to produce ampules by the old method of fire-shaping. Fires are for gas, air and oxygen.

PEKAY ELEVATOR BUCKET

Pekay Machine & Engineering Co., 100 North LaSalle Street, Chicago 2, Illinois, is producing an elevator bucket featuring an independent "Ejector Plate" which serves as the back of the bucket but which is attached to the elevator belt by an entirely separate mounting than that used for the bucket itself. The passage of this mounting over the radius of the head pulley moves the ejector plate in a strong sweeping action which dislodges the contents of the bucket.

Foundry sands, adhesive, sticky and bonded materials, etc., cannot withstand this automatic ejecting action. As a rigorous test, a foundry tamped bonded sand into several of the buckets with a wooden mallet. Every one discharged its complete contents when the mounting of the ejector plate passed over the head pulley.

The buckets, which are constructed of 3/16" steel plate, can be had either with or without reinforcement lip and can be immediately and easily substituted for old-style buckets on any elevator without major change in the elevator itself, utilizing standard hold punchings.

LIGHTWEIGHT SPRAY GUN FOR SAND BLASTING ON GLASS

Blasto Spray Gun Manufacturing Company, Los Angeles, California, has announced the development of a lightweight, all-purpose spray gun that can be used to sand blast designs and frosting on glass and plastics.

Designed to operate off small air compressors, the gun uses only 3 CFM at 30 pounds of air pressure. A specially designed, low pressure, high velocity head is standard equipment.

A non-bleeder type of spray gun, the air pressure is checked in the handle, but can be worked as a bleeder type by removing the trigger valve assembly which permits air to pass through the trigger hole when the gun is not in use. While the Blasto spray gun is a syphon-type gun, no air pressure is forced into the glass jar. The gun is constructed of solid aluminum alloy castings, precisioned machined, heavy brass fittings and chrome molybedenum heat-treated high velocity sand nozzle and air jet.

ELECTRONIC TEMPERATURE CONTROLLER

Thomas Edison, Inc., Instrument Division, West Orange, New Jersey, has developed a temperature controller using a single electronic tube with an electrical resistance type bulb for thermal pick-up and is of the on-off type.

The use of the resistance bulb permits location of the sensing element at a point remote from the control panel and eliminates the necessity of thermal compensation. The device, which is non-indicating, may be used to control temperatures to close tolerances in solids, gases or liquids. Units are available to cover the temperature range from —100° F to 1200° F and are adjustable within a range of several hundred degrees.

Supply voltage may be 115 or 230 volts, 50-60 cycle alternating current. Load capacity is 30 amperes at 115 volts, 20 amperes at 230 volts. Normal response time is under three seconds, due to the patented bulb construction.

THER-MONIC CORE BAKING TUNNEL

Induction Heating Corporation, 181 Wythe Avenue, Brooklyn 11, New York, has presented its Model M-800A Thermonic electronic core baking tunnel with an average baking cycle of only a few minutes and with a capacity of 650 pounds of cores per hour.

Electronic heating times are in the order of 20 seconds to a few minutes, whereas the minimum baking cycle in combustion ovens usually runs from one to four hours. Now cores can be baked as they are needed in the pouring room and changes in molding schedules can be effected without any thought as to what cores are in stock, according to the announcement. The rapid baking cycle also prevents core sagging during the baking operation.

After the baking cycle, the core plate emerging from the tunnel may go directly onto the inspection table.

NEW ZIRCONIUM OPACIFIER

Rohm & Haas Company, Philadelphia, Pa., is manufacturing a new zirconia base opacifier for porcelain enamels to be known as Lufax 77A. The product is designed primarily for zirconia opaque enamels and contains a mixture of controlled crystalline phases of zirconia which, in addition to imparting opacity, provides nuclei for the crystallization of zirconia from the molten enamel.

CATALOGUES RECEIVED

Brooks Rotameter Company, Box B-70648, Lansdale, Pa., has issued a catalogue covering its full line of rotameters for flow-rate measurement and control, including the "Full-View" rotameter with safety shielding for normal pressures and temperatures, the "Stain-Met" armored rotameter for high pressures and temperatures, the "Inductronic" rotameter for remote record, automatic control or totalization of flow rates.

The bulletin also describes the company's new "Sho-Rate" rotameter for purge systems and "Multi-Range" flow rate kit for research laboratories and pilot plants. Capacity chart, data sheet and dimension prints of each type of meter are included.

Hartford-Empire Company, Hartford 2, Conn., has issued a bulletin featuring its automatic glass level control system.

The bulletin explains carefully the system and shows a line drawing highlighting the features. A list of advantages with reasons why is given.

Polacoat, Incorporated, 2782 Highland Avenue, Norwood, Cincinnati 12, Ohio, is distributing a brochure featuring a Polacoat kit used for testing the condition of the surface of glass, as well as for producing light polarizing filters.

The Polacoat solution is discussed and various applications explained.

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AMERICAN WINDOW GLASS TO BUILD TWO MILLION DOLLAR PLANT IN OKLAHOMA

The erection of a completely new plant for the production of sheet glass expected to cost approximately two million dollars is now being designed for the American Window Glass Company. The plant will be built at Okmulgee, Oklahoma.

Design and construction has been scheduled to make possible limited production by October 1948. Structures in the new plant will include an automatic batch plant, furnace and machine buildings, cutting rooms, box shop, warehouse and other facilities.

Raw materials will arrive at the plant by rail and will be carried to the batch plant storage bins through track hoppers and elevators. Bins will be unloaded through a series of scales, feeders, belt conveyor and elevator. After mixing, the material will be carried to the furnaces by buckets on an overhead monorail system.

The furnace buildings and machine buildings will have a structural steel frame with corrugated galvanized steel roofing and siding. The cutting rooms will be constructed on a concrete foundation with concrete floor, concrete block walls and flat built-up roof on steel deck, all supported on structural steel frame. The box shop and the warehouse will be of the same construction as the cutting rooms.

DR. HENRY HAUSNER JOINS SYLVANIA ELECTRIC RESEARCH STAFF

The appointment of Dr. Henry H. Hausner as a member of the staff of the Metallurgical Research and Development Laboratories of Sylvania Electric Products, Inc. has been announced. Dr. Hausner will specialize in powder metallurgy for application to electron tubes, lighting and special products.

Formerly chief research engineer for the Ceramics and Steatite Corporation, Dr. Hausner was also chief electrical engineer for the Nichols Research and Engineering Corporation, electrical engineer for the War Department and a research engineer for the American Electro Metals Corporation before joining Sylvania. During the war, Dr. Hausner developed and patented hermetic seals for electronic equipment which were widely used in communications apparatus.

At the same time announcement was made of the election of Grenville R. Holden, Vice President of Sylvania Electric Products, as Director of Thorn Electrical Industries, Ltd. of London, one of the largest independent manufacturers of lighting products in Great Britain. Sylvania recently acquired a minority interest in the British company.

FOXBORO INSTRUMENT COURSES

The Foxboro Company, which has conducted training courses in the theory, application, operation and maintenance of industrial instruments since early in 1935, has announced its schedule for the remainder of 1948.

There will be five courses, each of two weeks' duration, during July, August, October, November and December. Courses will also be arranged for companies wishing to send a group sufficiently large to warrant a special class for the study of particular instruments and applications.

SAM TOUR & CO. ADDS GLASS SECTION

A new glass section has been added to the laboratory facilities of Sam Tour & Company.

Due to the increase in the use of glass, particularly for packaging consumer items, the new section will specialize in glass failures in an effort to contribute to the improvement of glass for containers and industrial applications, company officials stated.

The new Glass Section will be located in the company's building at 44 Trinity Place, New York, New York. It will be set up with the most improved glass testing equipment and will occupy space made available during recent enlargement of the laboratories.

HARBISON-WALKER PRESIIDENT RETIRES

Raymond Willey, President of Harbison-Walker Refractories Company, has retired as of July 1, according to company officials. He will be succeeded by Earl A. Garber, Vice President and General Manager of the company.

President of the company since 1939, Mr. Willey joined Harbison-Walker in 1901 as assistant to the supervisor of magnesite purchases in Budapest, Hungary. He returned to this country and in 1913 became assistant to the Vice President in charge of Operations. In 1917, he was elected a Director and in 1929 was named Vice President in charge of operations.

Mr. Garber joined Harbison-Walker in 1915 and served in several capacities until in January 1947, he became Vice President and General Manager.

BRITISH REPORT COVERS GLASS INDUSTRY IN GERMANY

A British Intelligence Objectives Sub-Committee Overall Report covering the glass industry of Germany during the period 1939-1945 has recently been published.

Contents of the book include discussion of fuels used, producers, furnaces, refractories, raw materials, production methods, production details, research facilities and researches, glass making machinery and the part of Australia in the German glass picture at that time. The text has been compiled by Professor H. Moore of Sheffield University.

CARL VAN LAATEN DIES

Carl Van Laaten, well known in the glass and chemical-consuming industries, died in Chicago on May 8.

Mr. Van Laaten, born in Chicago in 1890, entered the employ in 1909 of Edward Hill's Son & Company, then sole selling agents for the Michigan Alkali Company. In addition to this connection, he formed the Merchants Chemical Company in 1916 with E. V. Doyle, at that time Chicago Manager of the Michigan Alkali Company.

During the greater part of his selling career, he served as Manager of the Chicago, St. Louis and Cincinnati territories for the Edward Hill's Son & Company and later for the Michigan Alkali Company.

In recent years, Mr. Van Laaten made his headquarters in Chicago as Special Western Representative for the Wyandotte Chemicals Corporation, which succeeded the Michigan Alkali Company. He is survived by his wife and son.

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Properly applied Glass Colors by Pemco become a permanent part of the container. For the life of the container their clearness and beauty readily distinguish the trade name or trade mark the result of their application. If your problem is a new color; if it is matching an out of the ordinary color; if it is to find colors permanently resistant to alkalis and acids; if it is uniformity of product to assure smooth production flow; if it is lower end costs, Pemco can help you for these are the type of problems Pemco is solving every day.

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GLASS COLOR DIVISION

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NOT JUST AUTOMATIC
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EVERY HARTFORD-EMPIRE machine and service has been developed as a link in a production chain, in which each part serves to improve the performance of the entire system. Hartford-Empire equipment and services assure the integrated operation necessary for continued and predictable efficiency.
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AUTOMATIC GLASS LEVEL CONTROL SYSTEM — a super-sensitive and completely automatic control of glass level.
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L-O-F NAMES DE-ICING GLASS ELECTRAPANE

A transparent film of oxide 20-millionths of an inch thick applied to glass makes it possible to carry electric current in window installations. The new glass has been named Electrapane by Libbey-Owens-Ford Glass Company.

The development of the product was only recently made known after a patent had been granted the company. The thin, oxide film which makes the glass a conductor of electricity with the ability to heat quickly by electrical resistance, for all practical purposes is as durable as the glass surface itself, according to the company's announcement.

Because of the extreme thinness of the film, Electrapane is transparent. By transmitted light it is colorless. By reflected light, faint color hues are visible, but these are minimized by maintaining the film thickness at even quarter wave length multiples of yellow-green light and by placing the film adjacent to the plastic interlayer of a lamination where the refractive indices of the film and the plastic act to lower the reflection from that found at a film-air interface, it was further stated.

Electrical resistance properties of the glass are fairly constant up to approximately 450 degrees F., above which temperature the resistivity gradually increases. Electrapane operates equally well on AC or DC voltage. Electricity is fed into the glass by thin metal electrodes concealed along parallel edges of the glass.

WESTINGHOUSE APPOINTMENTS

Russell E. Ebersole has been named General Manager of lamp sales, according to a recent announcement by Westinghouse Electric Corporation, and H. G. Cheney has been named his assistant.

Mr. Ebersole, who succeeds William J. Massey, retired, takes over direction of the company's lamp sales activities, including commercial engineering and advertising and sales promotion. A member of the Westinghouse organization since 1922, he has been in charge of Lamp Division field sales since 1944.

Mr. Cheney joined Westinghouse in 1920 as an accountant in the engineering department. In 1928, he moved to the advertising and sales promotion department and in 1930, was transferred to the executive sales department. For the past four years, he has been assistant to the general lamp sales manager and supervisor of lamp sales contracts.

Announcement was also made of the appointment of Ralph R. Brady as Manager of commercial engineering for the Westinghouse Lamp Division. Prior to joining Westinghouse, Mr. Brady was manager of the Bloomfield branch of the Electrical Testing Laboratories for ten years. He has held various executive positions in the commercial engineering department during his connection with Westinghouse.

• Robert L. Warren, President of Brockway Glass Company, has joined the Industries Advisory Committee of The Advertising Council. As a member of the Committee, Mr. Warren will serve with William E. Levis, Chairman of the Board of Owens-Illinois Glass Company, representing the glass industry.

"Put it on the Blanchard"

All of these pieces—glass, jewels, sapphires, rubies, agate, pyrex, signal glass, quartz prisms and ceramics—were ground on the Blanchard #11 or #18 Grinder. The methods developed for grinding these materials are applicable to many other pieces. We invite inquiries regarding the grinding of these or any unusual materials. Write today and ask for the "Work Done on the Blanchard" book—it will be mailed free.

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STANDARDIZATION OF THE OPTICAL DENSITIES OF INDUSTRIAL EYE-PROTECTIVE GLASSES . . .

(*Continued from page* 380)

or magnesium cutting and welding, because they have also high absorption in the red. Alubro-Weld is available in three special shades and offers ample protection in the infrared. The lighter shades give insufficient protection in the ultraviolet. The Burt-Weld and G-1 aluminum welding glasses offer complete protection in the ultraviolet, but have high transmittances in the infrared.

Special blue glasses known by various names as "Melters Blue", "Cobalt Blue", "Pugh Glass" and "Ohio Blue" are available in as many as 6 to 8 slightly different densities, usually according to thickness. Representative samples were examined and their transmittances are shown in Figure 24. This type of glass is often demanded by operators of open-hearth furnaces, etc., in the particular shade with which the operator is familiar, because of the contrast in brightness that is obtained between the molten metal and the interior of the furnace. These cobalt glasses have high transmittances in both the ultraviolet and infrared regions of the spectrum.

The Bessemer lens (see Figure 25) is a dichromatic filter having transmittance bands in the yellow-green, near 560 millimicrons, and in the red above 650 millimicrons. This lens was developed[25] to replace combination yellow, blue, and red imported glasses, and blue-amber domestically produced glasses for use by the Bessemer blower in estimating certain color changes of the flame in the Bessemer steel making process. During the production of steel and cast iron by the Bessemer process, metal containing various impurities (primarily silicon, magnesium, and carbon) is loaded into a vessel and a blast of air shot through it for a period of 15 to 20 minutes. This oxidizes and then burns off the impurities in the order listed with a distinctive color for each oxide. As the "blow" progresses, the temperature of the material increases because of the rapid oxidation. The operator depends upon a photoelectric pyrometer and visual observation of the colors of the burning gases in determining the proper point at which to stop the "blow" and to pour the metal.

It has not been possible in this brief account to give data on all the available eye-protective glasses. However, a description of the method employed in the establishment of the shade-number standards together with data on different shade numbers, even down to the darker shades where the spectral transmittances are below 0.001 of 1 percent, is presented. Reference should be made to the complete report[21] for further information on this subject. The transmittance curves, presented herewith, are not only representative of the new industrial glasses which are available for use in welding and cutting of steel, aluminum, etc., and for use in the melting and manufacture of steel, glass, and other products, but illustrate the application of the special optical density standards in the accurate determination of the spectral luminous transmittance of very dense glasses.

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ALFRED UNIVERSITY CERAMIC COLLEGE GRADUATION

Fifty students received bachelor's degrees from the New York State College of Ceramics at Alfred University's 112th anniversary commencement exercises.

The University also conferred master's degrees on nine students and presented an honorary Doctor of Laws degree to Amory Houghton, Chairman of the Board of Corning Glass Works. Dr. S. R. Scholes, Dean of the College of Ceramics, presented Mr. Houghton for the honorary degree.

GLASS PRODUCTS MERGES WITH AMERICAN WINDOW GLASS

At the recent shareholders' meeting of the American Window Glass Company, the shareholders approved the merger of Glass Products, Inc., into American Window Glass Company and the recapitalization of American Window Glass Company as planned, by more than the required vote.

Some of the shareholders have notified the company of their intention to file appraisal proceedings and the Directors of the company are now giving consideration to the question of whether or when the merger and recapitalization should be declared operative.

TRUCTRACTOR FILMS SHOW MODERN MATERIALS HANDLING METHODS

The Industrial Truck Division of the Clark Equipment Company has announced the preparation of a series of films showing electric battery-powered and gas-powered fork lift trucks and towing tractors at work, including many phases of modern packaging, loading and handling.

The films are available on a loan basis upon request.

A. C. S. SECTION MEETING

The Trenton Section of the American Ceramic Society recently held its last spring meeting and the speaker of the evening was Frank Lobaugh, Manager of the Lumnite Division, Universal Atlas Cement Corporation. He discussed the use of refractory concrete in kiln and kiln car construction and gave examples of how it had been used to good advantage. He showed numerous interesting slides on its use in solving maintenance problems.

The Section's first fall meeting has been scheduled for September 24.

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* * * * * * * * * * * * * * * *

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FOR SALE

GLASS PLANT, CHICAGO HEIGHTS, ILLINOIS

By order of the United States District Court for the Northern District of Ohio, Western Division, Owens-Illinois Glass Company offers for sale as a unit all real estate, buildings, machinery, production equipment (not including molds), tanks and furnaces (except experimental machinery and furnaces) located at Chicago Heights, Illinois, and which were a part of the assets acquired by Owens-Illinois Glass Company from Kimble Glass Company on July 1, 1946.

In accordance with the order of the Court such property is offered for sale for cash to any purchaser approved by said Court, subject to prior sale, at the fair market value of said property as a glassware manufacturing plant, as determined by an appraisal made by The Lloyd-Thomas Company, which said appraisal has been duly filed with the Clerk of said Court at Toledo, Ohio., where it may be inspected. Additions and improvements made to the property described above since July 1, 1946, and prior to consummation of sale are not included in the appraised value aforesaid but are offered for sale as a part of the unit for an additional consideration equal to the cost thereof to Owens-Illinois Glass Company.

In connection with the sale of the property and additions and improvements thereto above described, Owens-Illinois Glass Company will assign or cause to be assigned to the purchaser thereof for the consideration hereinafter set forth, all its rights in and to the following machinery and equipment leased from Hartford-Empire Company situate on said premises on July 1, 1946, to-wit:

4—4 head I S machines with feeders, revolving tube drives and motors, and variable speed drives and motors

1—5 head I S machine with same

2—36" x 74' lehrs, gas fired with top vertical discharge, motor driven steel plate exhaust fan, and all regular equipment

The consideration to be paid by the purchaser to Owens-Illinois Glass Company for the assignment of its rights in the leased machinery aforesaid shall be cash in such an amount as will reimburse Owens-Illinois Glass Company for a fair proportion of any and all payments made in connection with said leased machinery by Kimble Glass Company or Owens-Illinois Glass Company which may be considered as costs of installation, advance payments for minimum annual royalties, license fees, parts, insurance and taxes.

In the event of such sale, possession will be delivered not later than six months after the consummation of such sale to a purchaser approved by the said Court.

Address all inquiries to

Owens-Illinois Glass Company
Attention: F. G. Morfoot
P. O. Box 1035, Toledo 1, Ohio

1947 SUPPLEMENT TO BOOK OF A.S.T.M. STANDARDS

The American Society for Testing Materials has issued the 1947 Supplement to keep up to date the triennially published book of A.S.T.M. Standards.

The 1947 Supplements recently issued in five parts give in their latest approved form some 330 specifications, tests and definitions which were either issued for the first time in 1947 or revised since their appearance in the 1946 book.

NORTHERN OHIO SECTION OF A.C.S. HOLDS MEETING

At the recent meeting of the Northern Ohio Section of the American Ceramic Society, the guest of the meeting was Walter Williams of the Ceramic Supply Company and present Chairman of the materials and equipment division of the Society.

Mr. Williams' subject was "Mechanization, An Aid to Quality Control", in which he described the layout of his company's new plant for producing saggers. He cited figures showing how mechanization had improved their control checks and, in turn, increased their production.

JOINT MEETING ON GLASS

A joint meeting of the International Commission on Glass and the Society of Glass Technology has been announced to take place from September 30 to October 2 at the Palace Hotel, Buxton, England.

In connection with the meeting, a Symposium of papers on "The Nature and Constitution of Glass" has been arranged and contributions to it have already been promised by research workers in the United States and Continental Europe, as well as by British workers.

PEMCO INCREASES CAPACITY FOR COLOR PRODUCTION

According to a recent announcement by Jake Eagle, Manager of Color Sales for the Pemco Corporation, the company has increased the production capacity for porcelain enamel colors, glass colors and glaze stains and colors.

In his announcement, Mr. Eagle further stated that manufacturing facilities for various Pemco colors and stains had been expanded almost one hundred per cent, and that these increased facilities had been made necessary in order to handle the greatly increased production of recent months.

CORNING APPOINTS RESEARCH CHEMIST

Dr. Joseph J. Rothermel, who recently obtained the Doctor of Philosophy degree from the University of Pittsburgh, has been appointed research chemist by Corning Glass Works at Corning, New York.

Dr. Rothermel's thesis was on X-ray absorbing glasses. The research was conducted under the joint direction of Drs. Kuan-Han Sun and Alexander Silverman.

• A new multi-million dollar chemical plant for the manufacture of silicone materials has been completed at Waterford, N. Y., by the Chemical Department of the General Electric Company, it has been announced. Consisting of six buildings and a chemical tank farm located on a 15-acre plot, the Waterford plant currently employs approximately 150 persons. This number may increase slightly when full production is attained.

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RESEARCH DIGEST . . .
(*Continued from page* 395)

tivity values obtainable on reduction of the glasses."

As the result of their investigations, Green and Blodgett found that: Glasses containing sufficiently high contents of lead, bismuth, or antimony oxides or combinations of these become electrically conducting when reduced in hydrogen by several hours' heating. The electronic conduction is maintained in a reduced surface layer whose thickness is somewhat less than 0.001 in. Results show that the surface conduction increases as the content of reducible oxide is increased. The conductivities of the lead glasses vary considerably with the reduction temperature while many lead-bismuth combinations show the same conductances over a wide range of reduction temperatures. The variations of conductance with changing reducible oxide contents or with temperature of reduction are believed to be due to the changing distances between conducting particles, that is increasing distances result in lower conductances. On the other hand, the conduction mechanism is dependent on the nature of the oxide glass structure surrounding the conducting particles. Thus the presence of alkali ions appears to decrease the conduction in all cases. In the lead glasses boric oxide as the network-former restricts electronic conduction. Barium oxide may be introduced into some of these compositions without appreciable effect on conduction while aluminum oxide generally decreases the conduction. The introduction of bismuth or antimony oxides into lead glasses definitely increases the conduction to a greater extent than can be explained on the basis of atomic substitutions. It must be concluded that this investigation is mainly exploratory in character but that the results clearly demonstrate the usefulness of this method for obtaining further evidence on both the atomic nature of glass and the electronic conduction of solids.

A method was worked out for applying a coating of a lead glass to borosilicate glasses. After treatment in hydrogen the coating had about the same resistance as plates of this glass which were sandblasted and reduced in hydrogen. A set of measurements of the resistance of a coating on the inner wall of a cylinder of Corning AO glass is given. The resistance was stable at 5 to 3 $\times$ 10^9 ohms per square area, and at voltages up to 90 kv. across 2.1 in. in an atmosphere of freon.

FIBERGLAS CORPORATION NAMES ASSISTANT TREASURER

Owens-Corning Fiberglas Corporation has named Elmer H. Weihe as Assistant Treasurer, according to a recent announcement made by that company.

Mr. Weihe has been credit manager of the company since 1942. He began his career in the glass industry in Evansville, Indiana, in 1917 when he entered the employ of the Graham Glass Company, then a subsidiary of the Owens Bottle Company, as assistant auditor. In 1931 he transferred to the Owens-Illinois general manufacturing department in Toledo and when Owens-Corning Fiberglas Corporation was formed in 1938, he joined the new company.

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PLATE GLASS
The Jumbo ROL-AWAY

The larger size, larger capacity of Rol-Away's new Jumbo model is a natural for working with extra-large office and store window glass. Nationally known glass companies such as Pittsburgh Plate Glass Company and W. C. Fuller and Company find that Rol-Away eliminates breakage and saves valuable manhours. This easy-to-operate Jumbo aluminum truck enables one man to handle materials which formerly required a whole crew.

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DIMENSIONS — 74" high, 72" long, 36" wide
CAPACITY—3,000 pounds
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SAFE—operator is protected; no slipping or tipping.
NO LIFTING—one man can load with ease; the leverage of Rol-Away does the job.
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HARBISON-WALKER APPOINTMENT

Arthur E. Currier has recently joined the research department of Harbison-Walker Refractories Company, according to a recent announcement from that company.

Dr. Currier received his Bachelor of Ceramic Engineering degree from Ohio State University in 1940 and did graduate work at the Ohio State Experiment Station on "The Use of Domestic Kyanite", a project sponsored by Johns-Manville Company.

After four years with the Engineer Corps, Dr. Currier returned to the Ohio State Experiment Station where he worked on a U. S. Potters Association Fellowship. He received his Ph.D. in March 1948.

CANADIAN GLASS INDUSTRY REPORT

The Canadian government reports that the importation of window glass during March, 1948 reached a total of 7,823,000 square feet.

At the same time it was reported that a nation-wide survey has revealed that the gross selling value of products in the Canadian glass industry decreased to $27,605,255 against $28,281,397 in 1946 and 1945, respectively, though there were 114 plants in the glass industry in 1946, as compared with 103 in the previous year.

The average number of employees in this industry rose to 5,921 who received salaries and wages totalling $9,278,360, with the cost of fuel and electricity at $1,863,561 and cost of materials, $10,583,240, as compared with 5,830 employees in the preceding year of 1945 when they were paid $9,043,864 in salaries and wages, with the cost of fuel and electricity amounting to $1,866,240 and cost of materials, $10,467,286.

The Dominion Glass Company, Ltd., has declared a dividend of 1¾ per cent on the preferred stock for the quarter ending June 30, 1948, and a dividend of 25 cents per share on the common stock of the company for the same period, both dividends payable July 15, 1948, to shareholders of record on June 28, 1948.

SOUTHERN ALKALI PROMOTION

Gustave Heinemann, since 1934 chief chemist at the Corpus Christi, Texas plant operated by Southern Alkali Corporation, will assume the additional duties of Technical Director, according to a recent announcement.

Prior to his association with Southern Alkali, Mr. Heinemann served as a chemical engineer for four years at Pittsburgh Plate Glass Company's alkali producing plant at Barberton, Ohio.

Mr. Heinemann attended the University of Minnesota where he graduated in 1929 with the degree of B. S. in Chemical Engineering. The following year he attained his M. S. in Chemical Engineering.

● Appointment of two field representatives to Libbey-Owens-Ford Glass Company sales distributor organizations in New York state has recently been announced. They are Arnold K. McClay to become associated with the New York City office and Jack C. Petersen who will go to Buffalo.

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FIRST SYMPOSIUM ON CRYSTAL CHEMISTRY . . .

(*Continued from page* 387)

complex ionic crystals. He constructed clay minerals from model ions. Dr. S. Zerfoss, Crystal Section, Naval Research Laboratory, discussed the inversions of A_2XO_4 type compounds which are of interest to ceramics. He provoked a lively exchange of opinions in the field. Dr. Charles H. Moore, National Lead and Rutgers University, provided a most thought promoting and stimulating proposal of new ideas regarding the controversial bond in metalloids.

The possibility of hearing and discussing problems of this nature in a forum where nobody has to commit himself to permanent labels justified the labors of those who originated the session. The hosts were warmly commended for arrangements scientific and personal and the meeting ended on a humorous note under the last hour chairmanship of H. M. Kraner.

TECHNOLOGICAL PROBLEMS IN THE USE OF ALTERNATE FUELS IN THE GLASS INDUSTRY . . .

(*Continued from page* 386)

tually the operator is caught between the two limits of filling the producer to the top and/or plowing the ashes down so far that the incandescent zone reaches the blast hood and burns it off. Also it seems that even though the ash fusion is high, in such circumstances clinkers will form anyway. The water-jacketed type of producer is better in this respect.

The coal marked XX was by far the best producer coal of all, combining low ash with high fusion which is a logical combination. Unfortunately XX Mine played out this year and the one marked X the same in 1944, bear- coming scarce in spite of the millions or billions of tons ing out the fact that high quality producer coals are be- of Bituminous coal in reserve.

DALE TORGESON JOINS HARBISON-WALKER RESEARCH DEPARTMENT

The appointment of Dale Torgeson to the Research Department of Harbison-Walker Refractories Company has recently been announced.

Mr. Torgeson was formerly chief chemist for the Northwest Magnesite Company and more recently, he has been with the Bureau of Mines at Boulder City, Nevada, and Berkeley, California, where he did development work in pyrometallurgy and thermodynamics.

THATCHER NAMES MANAGER OF ELMIRA PLANT

It has been announced by Thatcher Glass Manufacturing Company that Harry J. Mullany has been appointed Manager of the company's Elmira plant.

Mr. Mullany was formerly the Manager of Thatcher's Olean plant. He held the position of Plant Manager at the Elmira plant until late in 1945 when he took over the same duties at Olean. Mr. Mullany has been associated with Thatcher for eleven years.

200-INCH CORNING MIRROR GOES INTO SERVICE . . .

(*Continued from page* 381)

to gravity, is not only materially less than that of the conventional lattice type tube, but the residue bending does not affect the alignment of the various mirrors carried by the tube.

The tremendous size of the telescope posed the problem of developing a more elaborate control system than ever before used by astronomers. An electric remote indicating system of right ascension and declination is used. The telescope can automatically be set to predetermined star positions, and is accurate to one second of arc. A push-button control sets the telescope in motion. It moves to the predetermined position and then follows the star across the skies.

The initial research program for the 200-inch telescope will be one designed to carry on where the 100-inch Mt. Wilson telescope leaves off in confirming, if possible, many existing theories. Such projects might concern the relative abundance of chemical elements in stars; or cosmology, the structure and behavior of the universe as a whole; or What about Mars?

These are only a few examples of the research that will get underway when the Mt. Palomar 200-inch telescope is put into operation. It is logical that this program be arranged so as to take up where findings by the 100-inch Mt. Wilson telescope leave off. However, there is already some speculation concerning the greater horizons that will present themselves as astronomers progress into space with the greatly increased facilities of the Mt. Palomar telescope.

BORIC OXIDE—ITS CHEMISTRY AND ROLE IN GLASS TECHNOLOGY . . .

(*Continued from page* 390)

ternary system Na_2O-B_2O_3-SiO_2. It is not possible here to discuss in detail the wealth of information obtained in these years. It is also unnecessary to present the explanations which were offered for the "anomalous behavior" of boric oxide. The combined efforts of these workers made it possible to present the low temperature thermal expansion of sodium-borosilicate glasses as a function of composition. (Table XI)

Optical Properties

The first glass melters to pay attention to boric acid as a potential glass constituent were interested in improving the optical properties of glass. Other valuable properties of boric acid as a glass constituent were discovered in the search for glasses with new optical properties. Today boric acid still represents an important constituent of optical glasses. It is a major constituent of the borosilicate crowns, of some special glasses derived from zinc and cadmium borates and of the borates of lanthanum, tantalum and thorium. The value of boric oxide as a constituent of optical glasses dates from the discovery (Abbe and Schott) that it increases the dispersion in the long wave part of the spectrum and decreases this value for shorter wave lengths.

In spite of the importance of boric oxide as a con-

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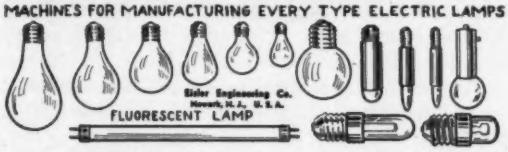

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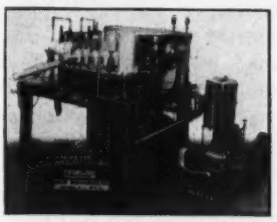

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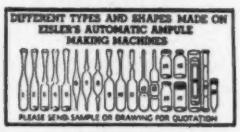
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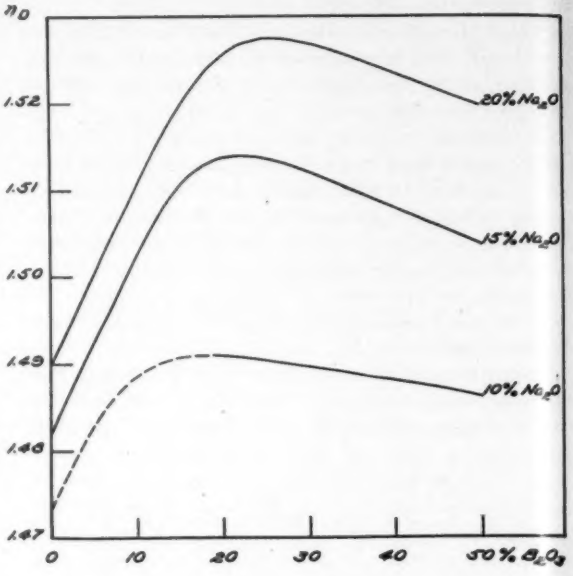
stituent of optical glasses, the optical properties imparted to glasses by boric acid shall be treated here only very briefly.

Next to thermal expansion, the refractive index was chiefly responsible for calling attention to the failure of additivity as a principle governing the properties of glasses. E. Zschimmer (1905), in a discussion on the physical properties of glasses as affected by their chemical compositions, emphasized how erroneous it would be to expect these properties to be additive. He illustrated his statement by giving the values of the refractive index of potassium borosilicate glasses. If increasing amounts of B_2O_3 are added to a potassium silicate glass, these values go through a maximum in the region of 15% B_2O_3.

The optical properties of a glass can be measured with great accuracy. As a result, the refractive index of borosilicate glasses provides the most accurate information concerning the changes taking place in a glass structure at room temperature over a period of many years. As an example the work of A. Winter-Klein shall be mentioned.

The refractive index is the first property which gave proof of the erroneous assumption that the difference between annealed and chilled glasses can be explained on the basis of mechanical forces alone. A. H. Lebedeff (1921) demonstrated that the difference between the refractive indices of a chilled and an annealed glass cannot be explained on the basis of mechanical deformations. The full significance of this discovery does not seem to be understood by all workers in this field. As a result, from time to time a new "explanation" is presented for the rate of annealing of glass, especially for the empirical equation given by Adams and Williamson.

FIGURE 10



The optical properties of sodium borosilicate glasses were determined by T. H. Wang and W. E. S. Turner (Table XII) and correlate the values of the refractive index (n_D), dispersion ($n_F - n_C$) and the Abbe value

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TABLE XII

Optical Properties of the Soda-Boric Oxide-Silica Glasses Studied. Rectified Results.

Chemical Composition.		Optical Properties.		
Na_2O, %.	B_2O_3, %.	N_D.	$N_F - N_C$.	v.
20	6.8	1.5060	0.00819	61.9
	14.3	1.5201	0.00815	63.8
	22.5	1.5257	0.00824	63.9
	28.1	1.5244	0.00819	64.0
	32.5	1.5238	0.00810	64.5
	34.1	1.5242	0.00811	64.5
	47.5	1.5229	0.00812	64.5
15	9.5	1.5040	0.00795	63.4
	20.0	1.5145	0.00791	65.4
	30.0	1.5121	0.00790	64.9
	34.0	1.5111	0.00787	65.0
	41.6	1.5076	0.00788	64.5
	48.5	1.5039	0.00789	63.9
	52.6	1.5048	0.00789	64.0
10	17.7	1.4876	0.00745	65.5
	22.3	1.4888	0.00744	65.7
	30.5	1.4881	0.00760	64.2
	43.8	1.4869	0.00760	64.0

$\frac{(n_D - 1)}{(n_F - n_C)}$ with the composition of these glasses.

Like other properties, the refractive index is strongly affected by the equilibrium between BO_3 and BO_4 groups. The shift of this equilibrium with temperature and heat treatment, accounts for the pronounced effect which annealing and aging exerts on the optical properties of borosilicates. This equilibrium is not only a function of the B_2O_3 content but is also dependent on the alkali content of the glass. As a result the maximum n_D value obtained by replacing SiO_2 by B_2O_3 depends on the Na_2O content of the glass. (Fig. 10)

R. W. MCKINLEY JOINS PITTSBURGH CORNING DEVELOPMENT GROUP

Robert W. McKinley, who, until recently, was on the staff of the Illuminating Engineering Society, has joined Pittsburgh Corning Corporation's newly formed Development Group. Mr. McKinley will devote his efforts to daylighting problems to assist designers and purchasers of Pittsburgh Corning glass block installations.

During the war years, Mr. McKinley was specially assigned as an electrical engineer for the Bureau of Ships. His next Navy assignment was the coordination of glass and plastic filter development and production work at several industrial university and government laboratories.

• Announcement has been made of the appointment of M. D. Burch as Manager of the Kansas City, Kansas, plant of the Owens-Corning Fiberglas Corporation. Mr. Burch has been associated with the company since 1940.

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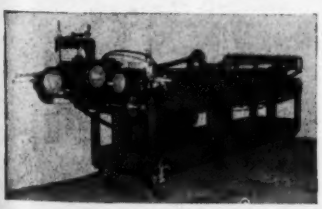

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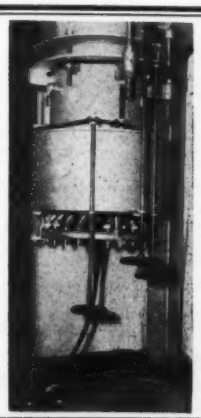

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